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Noyes's College Text-Book of Chemistry

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336 pages of text. 12mo

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As with all textbooks for beginners, two purposes have been constantly kept in mind while writing the book: the presentation of a few of the multitude of chemical facts which touch our modern life, in such a manner that they can be clearly understood, and the discussion of the theories and principles around which all our chemical knowledge is grouped.

The teacher of chemistry is embarrassed by the vast and ever increasing amount of knowledge at his disposal and is often tempted to present many more topics than the student can possibly remember. In trying to avoid this difficulty many facts ordinarily included in an elementary textbook have been omitted and those which are given are brought as far as possible into close logical relations.

The summary at the close of each chapter is a somewhat unusual feature of the book. It is hoped that these summaries will be found useful.

Success in the study of chemistry depends especially on the ability to learn new facts in their relation to those which have already been acquired and on the cultivation of a logical as distinguished from an arbitrary memory. The exercises at the close of each chapter and questions occasionally inserted in the text are designed to assist the student in this direction.

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THE SCIENTIFIC MONTHLY

DECEMBER, 1919

THE MECHANISM OF EVOLUTION IN THE LIGHT OF HEREDITY AND DEVELOPMENT[1]

By EDWIN GRANT CONKLIN

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THE general theory of organic evolution undertakes to explain by natural processes the origin of the existing world of living things, and in particular it seeks to account for three classes of phenomena, namely, (1) The diversities (varieties, species, genera, etc.) of the living world; (2) progressive organization (increasing complexity of structure and function) from the lowest to the highest organisms and (3) the fitnesses (adaptations, etc.) of living beings. Its aim is nothing less than a mechanistic explanation of the origin, development and present state of the entire world of life; this is really an enormous undertaking and it is not surprising that this ultimate objective has not yet been reached, indeed it is probable that it may never be fully attained; but at least the problems of organic evolution are in process of being more clearly defined and some promising beginnings have been made toward their solution. To insist, as some have done, that the theory of evolution has failed because it has not yet solved all of these problems is to underestimate both the magnitude of the problems concerned and the progress which has been made toward their solution; to reject evolution, as others have done, because the problems are too great to be solved by the scientific method, is to renounce the slow and sure progress of science in favor of pure speculation and mysticism in which no progress at all is possible.

Scientists no longer discuss the question as to whether evolution has occurred, but there is much conflict of opinion as to how it has occurred. The fact of evolution stands fast; present

[1] William Ellery Hale Lectures before the National Academy of Sciences, Washington, April 16 and 18, 1917.

uncertainties, hypotheses and theories concern only the factors. Unfortunately this distinction between fact and factors has not been appreciated by many persons who are not students of this subject and consequently they have assumed erroneously that doubts as to the latter implied uncertainty as to the former. The two great systems of evolutionary philosophy, known as Lamarckism and Darwinism, are hypotheses as to the factors of evolution, and, if one or both of these should prove to be erroneous, it would not shake our confidence in the truth of evolution itself.

The mechanism of organic evolution is an enormous subject and many phases of it I should be unable to present except in a superficial manner; fortunately a comprehensive discussion of this topic is rendered unnecessary by the lectures of my immediate predecessor in this series.[2] I shall therefore limit my discussion to experimental and analytical studies of inheritance and development in their bearings on evolution. Even in this more limited area I must draw largely upon the work of others. My own researches have lain very largely in the domain of cellular biology and doubtless to many naturalists of the old school this field seems very remote from that of the origin of species. But in biology all roads lead to evolution and, though some of these are highways and others only by-paths, the inhabitant of any quarter of this world may come to its center by the road which passes his own door—by which simile I hope to forestall the criticism that my own field of work does not lie on certain main highways of evolution and that I do not attempt in these lectures to traverse all the routes that lead to the Eternal Theory.

I. Evolution, Historical and Experimental

In the development of science there has been a general movement from the methods of observation and description to those of analysis and experiment. Biology as a whole is just now making this transition; physiology has long been experimental, but only within the past quarter century have experimental methods been used extensively in the study of morphology, embryology, heredity and evolution. Biology is no longer a study of living things with the life left out, and evolution is no longer merely a study of the beaches where the tides of life have been. For long, evolution was studied and regarded merely as a past process which had flourished mightily

> In the dark backward and abysm of time

but which had practically ceased to-day. As a historico-

[2] Henry Fairfield Osborn, "The Origin and Evolution of Life."

scientific subject its results were studied and their cause surmised—all at very long range. As a past process it was approached only through the static branches of biology, such as Classification, Morphology, and Paleontology.

1. *Classification and Evolution*

To Darwin and his contemporaries evolution was largely a question of species and their origin, although it is true that Darwin laid much broader foundations for his theory than can be found in Classification alone, extending them into almost every field of biology and thus anticipating many recent developments of this subject. Nevertheless, to most naturalists of that period the transmutation of species seemed to be a problem for the systematists. It was in his famous "Essay on Classification" that Louis Agassiz attacked the new theory, and it was in the field of systematic botany that Asa Gray gave it such effective support. I remember with what scorn I once heard Cope say of Weismann, "He does not know species, and yet he presumes to discuss their origin." Now we ask, "Does any one know species?" and we look to the experimentalist for an answer, for the geneticist has shown how extraordinarily complex a species may be. Now we recognize that the evolution of a Linnean species is a problem akin to the origin of genera or larger groups, to be approached only by analogy and speculation. The experimental evolutionist deals with variations, mutations, elementary or incipient species which can be studied effectively only in pedigreed cultures.

2. *Morphology and Evolution*

The earlier morphologists studied the structure of various organs and systems in different species and in different stages of individual development and guessed more or less shrewdly as to the manner in which these structures had evolved. It is amusing now to recall how almost any group of organisms could be shown, by those who had made a special study of that group, to be ancestral to many other groups and how easy it was to construct "phylogenetic trees" or to explain the origin of particular structures by pure speculation. Whenever modifications of a structure could be arranged in a nicely graded series it was assumed that the actual course of the evolution of this structure had been determined, and not infrequently it seems to have been assumed that the course of evolution revealed its cause. Now we know that the minor changes in evolution do not always occur in a nicely graded series, but sometimes by sudden or dis-

continuous changes, while the course of evolution reveals only the direction and area in which its causes must operate, but not the causes themselves.

3. *Paleontology and Evolution*

Of all students of evolution the paleontologist has the most direct evidence as to its general course in the past but he has also the most indirect and uncertain means of determining its intimate causes, for he is farthest removed from it as a living process which can be dealt with experimentally. Consequently for the paleontologist as well as for the systematist and morphologist the methods and causes of evolution afforded a fertile field for an active imagination and as a result almost every possible theory was proposed, but none were demonstrated. The subject appealed to imagination, but not to verification.

4. *Experimental Evolution*

As long as evolution was regarded merely as a past process it could be studied only as an historic phenomenon. The recognition of evolution as a present process makes it at once an experimental as well as an historical science, and its problems are not merely those of the systematist, morphologist and paleontologist, but also those of the geneticist, embryologist, cytologist, physiologist, and bio-chemist. In short all branches of biology now center in this great theory. Furthermore, the only possible method of really determining the causes of evolution and of demonstrating the mechanism involved is by means of experiments.

(*a*) *Deals only with Diversities or Minor Changes.*—The study of contemporary evolution must of necessity deal with relatively minute changes in organism, with the production of mere diversities. The greater steps in evolution, such as the origin of species, genera and larger groups, and all progressive evolution, can not be dealt with experimentally unless such experiments are continued for long periods of time or unless artificial means are found of speeding up the evolutionary processes. Indeed it may be objected that until these minor changes have accumulated so that they actually give rise to new species comparable to those existing to-day in nature, we shall not be sure that they are real steps in evolution,—the materials out of which the many diverse forms of animals and plants have come into existence. Unfortunately this is only too true, and consequently evolution in its larger aspects is now and must long remain a theory rather than a demonstration, and yet the evi-

dences that some of these minor changes, such as variations and mutations, are first steps in the making of species and still higher groups is so extremely probable that it would be unreasonable to deny it. It is at least a probable and reasonable hypothesis and we know of no other which is either reasonable or probable.

(*b*) *Rise of Experimental Biology.*—During the last two decades of the nineteenth century the experimental method began to be used in the study of ontogeny and phylogeny and an indirect though most important result of such experiments was the introduction of a more critical spirit into morphology and a growing dissatisfaction with speculations on the course or cause of phylogeny. For some years there was conflict between the "pure morphologists" and the "experimentalists" as to the relative value of observation and experiment, but now so completely has our point of view changed that morphology as a purely observational study of dead "material" has almost ceased to exist, and in many institutions professorships in morphology have become professorships in experimental zoology or botany. And yet there is no magical power in experimental methods which renders the older methods of observation antiquated or useless. As a method of investigation experiment alone is no better and probably is not as good as observation alone; it is only when experimental methods are used to supplement observational ones that the best results are obtained.

(*c*) *Iconoclasm of Experimentalists.*—The experimental method, whether in morphology, embryology, or evolution is "nothing if not critical." In the first enthusiasm for the new method its advocates began by discrediting or discarding conclusions based upon mere observation and reflection. But scientific theories are not necessarily false because they have been come at by observation or logic; clear thinking is essential to scientific progress as well as careful experiments, and brains as well as eyes and hands play an important part in the discovery of truth. Nevertheless there is probably no other scientific doctrine which shows a greater need of caution, criticism and experimental confirmation than does the theory of evolution. In evolution no less than in other scientific fields frequently the most complex hypotheses are devised to account for things which have no real existence, as for example attempts to explain the hereditary transmission of acquired somatic characters, the telescoping of phylogeny into ontogeny, the transformation of one adult organism into another, etc. Science sometimes becomes so lumbered up and confused by many false theories that the best way of

advancing knowledge is by clearing the ground of errors, and this is especially true of evolutionary theories because of their appeal to imagination and their difficulty of verification.

(*d*) *Extravagant Hopes of Experimentalists.*—In the first enthusiasm over the application of experiment to the problems of evolution many extravagant hopes and predictions were made. Not only species, but even whole faunas and floras were to be artificially made "while you wait." But organisms have shown themselves to be wonderfully stable and resistant to change. Modifications of all sorts can be produced but few if any of these are inherited. The living thing which is delicate and plastic beyond all comparison is yet remarkably stable and stubborn. The results of experimental evolution as compared with the anticipations of twenty years ago have been distinctly disappointing; and yet progress has been made, and in particular many facts are more definite, many ideas more clear and many old theories have been shown to be untenable while a few have been more firmly established than ever before. Probably more progress has been made since the year 1900 in understanding the factors of evolution than in all previous centuries. And this is true largely because of the epoch-making work which has been done during the past fifteen years in bringing to light the factors of individual development.

5. *Genetics and Cytology—the Recent Lines of Progress*

The two fields in which our knowledge of the causes of evolution has made the greatest and most substantial progress within recent years are genetics and cytology, the one dealing with the inherited characteristics of successive generations of individuals, the other with the cellular bases of these characteristics in the germ cells and the transformations which these undergo in development; the former with the analysis of the developed organism into its constituent characters, the latter with the analysis of the germ cells with especial reference to the material basis of heredity. Although at first these two lines of work seemed very distinct the researches of the past fifteen or twenty years have shown that they are most intimately related and each has shed a flood of light upon the other. In the combination of these two lines of research so totally different in methods and apparently so unrelated in results, our knowledge of the methods and causes of evolution has been greatly extended. For the first time we know pretty definitely where to look for evolutionary changes, for the first time we are getting at the real mechanism of evolution.

Since the rediscovery in 1900 of the long-forgotten principles of inheritance, which were first made known by Mendel in 1866, remarkable progress has been made in the field of genetics—indeed almost all that is known concerning the exact manner of hereditary transmission has been learned since that year, and it is probable, as Morgan has said, that the fundamental principles of such transmission have already been discovered. The great and almost endless problems which stretch out before the geneticist have to do with a more minute study of the factors or causes of hereditary transmission. In similar manner the grosser facts as to the structure and development of the germ cells and as to the transformation of the fertilized egg into the embryo and adult are well known, but we have made the merest beginning in the study of the causes of this development and of the exact manner in which the germinal organization is transformed into developed characters. Development is indeed a vastly greater and more complicated problem than heredity, if by the latter is meant merely the transmission of germinal units from one generation to the next.

Thus the study of genetics, cytology or of any other science repeats the same general process which has characterized the study of evolution itself,—the outstanding facts are first established with relative ease, the factors are determined only after prolonged research. Furthermore the discovery of "the cause" of any phenomenon evermore leads to new inquiries as to the cause of this cause, so that research is never finished and knowledge is never complete.

II. Ontogeny and Phylogeny

Intimate Relations of the Two

Ontogeny or the origin of individuals and phylogeny or the origin of races are two different aspects of one and the same thing, namely organic development. There is a remarkable parallelism between the two, and in particular the factors or causes of development are essentially the same in both. Phylogeny is a present process as certainly as is ontogeny. Just as the earth rotates on its axis, revolves in its orbit and the whole solar system moves through space, so organisms undergo embryonic development, specific development and phyletic development, all being parts of one great process. All detailed study of evolution is necessarily a study of successive generations of individuals, and all analytical or experimental study of the causes of evolution resolves itself into a study of the factors involved in the genesis of individuals; there is no other possible

method of approaching the problem. For this reason the student of ontogeny is especially well fitted to deal with the factors of phylogeny. The study of the factors involved in the genesis of individuals under various conditions of inheritance and environment reveals all that can certainly be known regarding the methods and causes of the evolution of races and species.

1. *Development is Real and not Illusory*

Ontogeny or the development of an individual from the egg to the adult condition consists in progressive, coordinate differentiation of both structures and functions. To a certain extent differentiations are already present in the germ cells, but during the course of development their number is greatly increased. This increase in differentiation is caused by modification of previously existing differentiations, by transformation rather than by formation *de novo*, by evolution rather than by creation. New things appear in the course of ontogeny because of new combinations of things already present, just as new chemical substances with new qualities appear as a result of new combinations of elements.

In similar manner evolution is progressive diversification and adaptation. New species, new adaptations, new forms and new functions appear in the course of evolution because of new combinations of characters already present, or rather of the elements out of which characters are built. If any Mendelian of the stricter sort is inclined to question this statement and to affirm that characters or their germinal factors come out of any combination exactly as they went into it and that they have therefore suffered no permanent change, let him consider that any permanent change or mutation of a germinal factor or gene must consist in some new combination of the elements which go to make up the factor itself. For the very possibility of any change or mutation proves that the thing which changes is composed of more elementary units, and this is true not only of organisms, characters and germinal factors, but also of molecules and atoms. Those things only can be absolutely changeless which are absolutely elemental, and *vice versa*, those only are absolutely elemental which are absolutely changeless. *Organic evolution must of necessity consist in new combinations of the parts of which organisms are composed, whether those parts be organs, characters, genes, molecules or atoms.*

Neither ontogney nor phylogeny consists in making visible what was present but invisible before, much less is it a mere simplification of an original complex by a sorting out of certain

characters or factors of characters. It will be shown in a later section that ontogeny does consist to a certain extent in sorting out different materials present in the egg and in the isolation of these materials in different cells, but there is also a progressive formation of new materials during the course of development; there is in development real increase of complexity in which new characters appear by a process of "creative synthesis"; new combinations of the same old elements give rise to new qualities, new forms, new functions. In short, development is real and not illusory, and what is true of ontogeny in this respect is equally true of phylogeny.

2. *Development is Progressive and not Retrogressive*

Of all false theories and erroneous opinions one of the most far-reaching and misleading in its effects is that which may be called the inverted view of development, a view which regards the adult organism as the starting point in ontogeny or phylogeny and which then attempts to explain the transfer of developed characters from this to the germ. This inverted view of development is responsible for almost all of the false theories of development and evolution which now incumber the science of biology.

(*a*) *Inverted View of Ontogeny.*—Before Weismann a false trend was given to theories of development by neglecting or misconstruing one of the most elementary facts of ontogeny, viz., that development proceeds from the egg to the mature organism and not in the reverse direction. It was known, of course, that the egg produces the hen, but it was believed that the hen in turn produces other eggs, so that the life cycle was thought to consist of a progressive phase from egg to hen and a regressive phase from hen to egg (Figs. 1 and 2). It seemed evident that the mature organism manufactured the germ cells, and consequently, it was supposed that characters of the adult organism could be "reflected on" or condensed in the germ cells and then reappear in the next generation. Darwin's hypothesis of "pangenesis" made this general conception more precise by assuming that every cell of the body contributes particles or gemmules to the formation of the germ cells.

Based on Erroneous Cell Theory.—This inverted view of development, namely that mature organisms make the germ cells, is the result in large part of erroneous opinions as to the manner of origin of cells in general and of germ cells in particular. From the time of the work of Casper Friedrich Wolff (1759) to that of Remak (1841) it was maintained that "ves-

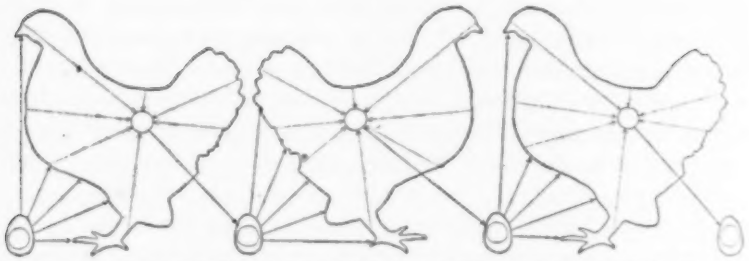


FIG. 1. DIAGRAM SHOWING THE ERRONEOUS VIEW THAT THE BODY OF HEN PRODUCES THE EGG (dotted arrows), while the latter in turn produces the body of the hen but not the egg.

icles" or cells appeared as droplets in a fundamental substance, or "as bubbles of gas appear in fermenting dough." New cells were supposed to appear between the old ones by a process known as "free cell formation." A principal feature of the cell theory of Schwann (1839–41) was that new cells arise in a homogeneous ground substance, the cytoblasteme, "like crystals in a mother liquor." On the other hand Remak (1841) proved that cells arise by division of preexisting cells, but for a long time "free cell formation," or the formation of cells *de novo*, was still maintained to be one of the methods by which new cells arise.

This antiquated conception as to the origin of cells is still responsible for much rubbish in our theories of evolution and development, for even at the present day many theories which grew up under this old conception are still maintained. If earlier evolutionists had known that every cell comes from a preceding cell by division and that it thereafter remains absolutely distinct from other cells, taking into itself no living substance from without but manufacturing its own protoplasm from food substances, there probably would have been no doctrine of "pangenesis," of the "reflection of adult characters on the egg," of the inheritance of developed somatic characters—no inverted views of development, heredity and evolution.

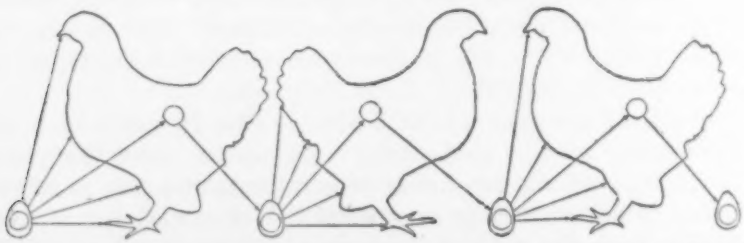


FIG. 2. DIAGRAM SHOWING THE TRUE VIEW THAT THE EGG PRODUCES THE BODY OF THE HEN AND ALSO THE EGG.

The cellular history of development has demonstrated that adult organisms do not manufacture germ cells and transmit their characters to them. Neither germ cells nor any other kind of cells are formed by the body as a whole, but every cell in the body comes from a preceding cell by a process of division and it

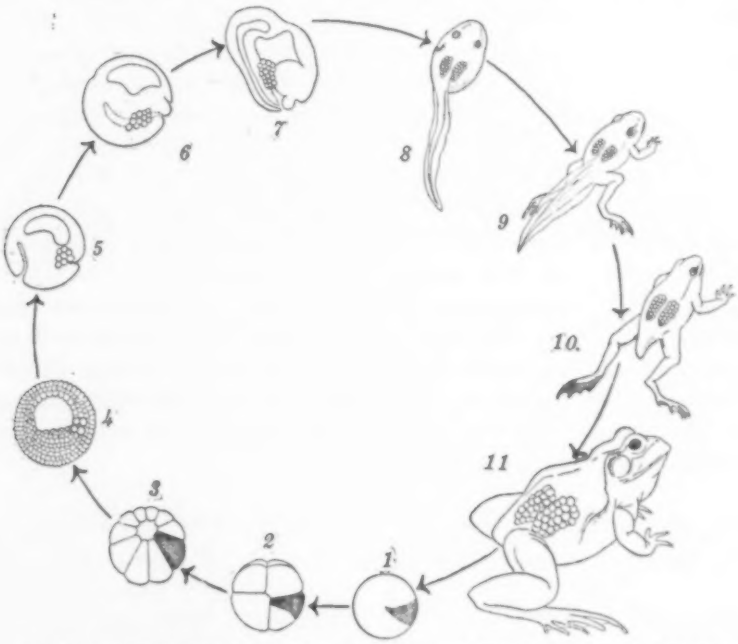


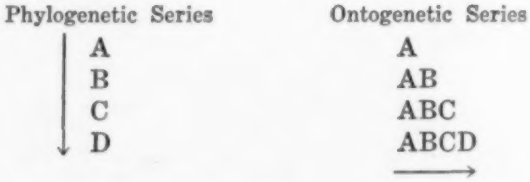
FIG. 3. DIAGRAM OF LIFE CYCLE OF THE FROG SHOWING THE STEPS BY WHICH THE EGG GIVES RISE TO THE BODY OF THE FROG AND TO OTHER EGGS. 1. Fertilized egg; the stippled area is the mesodermal crescent from which the germ cells come. 2. Eight cell stage. 3. Thirty-two cell stage. 4. Blastula showing germ cells in heavy outline. 5–7. Early to late gastrulæ showing germ cells in heavy outlines. 8–9. Early and late tadpoles with germ cells as in preceding figures. 10–11. Metamorphosing and adult frogs containing germ cells which come in direct lineage from the egg shown in 1.

grows, not by contributions of protoplasm from other cells, but by building up its own protoplasm from food substances; and germ cells are formed not by contributions from all parts of the body, but by division of preceding cells, which are derived ultimately from the fertilized egg. Development is not a process which goes forward at one phase and backward at another, but is always and everywhere a progressive movement from the egg to the adult and never one in the reverse direction (Fig. 3). End stages are not added on to previously completed ontogenies for every inherited change, whether of an end stage or of an earlier one must be represented by some change in the germ cell itself.

(*b*) *The "Recapitulation Theory."*—That there is a certain parallelism between the stages of ontogeny and those of phylogeny has long been known, but there has been much difference of opinion, and there is now a widespread misunderstanding as to the significance of this parallelism.

(1) *Truth and Error of Theory.*—The "fundamental biogenetic law" of Haeckel affirms that "ontogeny is a brief recapitulation of phylogeny" or, as some one has picturesquely expressed it, "every organism climbs its own ancestral tree."

Various other hypotheses such as Lankester's "precocious segregation" and Hyatt's "law of acceleration" taught that adult characters tend to appear at earlier and earlier stages in ontogeny, because they are "reflected back upon the germ cells" and thus that what were at one time "end stages" in ontogeny are crowded back into earlier stages, while new end stages are added. The "fundamental biogenetic law" of Haeckel was based entirely upon this idea that in the course of evolution new end stages are added to the ontogeny as it had previously existed. This conception may be represented by the following diagram in which the successive stages in phylogeny and ontogeny are represented in alphabetical series:



Thus the ontogeny of each of these phylogenetic stages was supposed to recapitulate the entire evolutionary series.

And yet among higher forms there are very many adaptations to embryonic and larval life which have no counterpart in lower forms and which indeed could not exist in free-living organisms; such are the embryonic membranes of higher vertebrates, the yolk-sac of fishes, and the modifications of development in these forms and in many of the invertebrates due to the presence of much yolk, the extraordinary modification of the larvæ of many parasites, and the remarkable differences in development which are found in different species of almost every class of animals. Such differences in the ontogenesis of organisms which are otherwise closely alike demonstrate that certain evolutionary changes may occur in embryonic stages without greatly modifying adult stages.

On the other hand, in many cases adult stages have under-

gone much greater changes than have embryonic ones; for example Ascidians are known to belong to the phylum Chordata, *Sacculina* to the Arthropoda, *Myzostomum* to the Annelida, etc., only because in these cases embryonic or larval stages preserve ancestral characters long after adult stages have lost them. In short *evolutionary changes may affect any portion of the life history, and therefore the course of ontogeny is not a sure indication of the course of phylogeny.*

It thus became evident that earlier phylogenetic stages were not always reproduced in the ontogeny and consequently a distinction was made between those ontogenetic stages which repeated the phylogeny and were called by Haeckel "palingenetic" and those which did not and were called "cœnogenetic." Consequently the phylogenetic and ontogenetic series were represented as follows:

Phylogenetic Series	Ontogenetic Series
A	A
B	aB
C	abC
D	abcD

Or since ontogeny is greatly shortened as compared with phylogeny the course of the two might be represented by the diagram on p. 494 (Fig. 4).

(2) *Embryonic Homologies and their Causes.*—Nevertheless, many organisms which differ widely in adult stages reveal a surprising degree of resemblance in embryonic stages and in general embryonic resemblances appear to be more persistent than adult ones. It is certainly no mere accident that practically all animals begin their individual existence as fertilized eggs, that before or during fertilization all eggs produce two polar bodies, that in animals as far apart as flatworms, annelids and mollusks the early cleavages of the egg are fundamentally alike and that where differences exist they have led to the discovery of rudimentary cells in one form corresponding to well-developed cells in another (Fig. 5). It is no accident that the eggs of all chordates have the same type of cytoplasmic localization, that all develop a notochord and nervous system and mesoderm in fundamentally the same way, that all vertebrates whatever have gill slits in embryonic or adult stages, etc. These and thousands of other resemblances of the same sort can be explained only by assuming that they are homologies or inherited likenesses and that forms showing these likenesses are genetically related. But this does not mean that in higher animals addi-

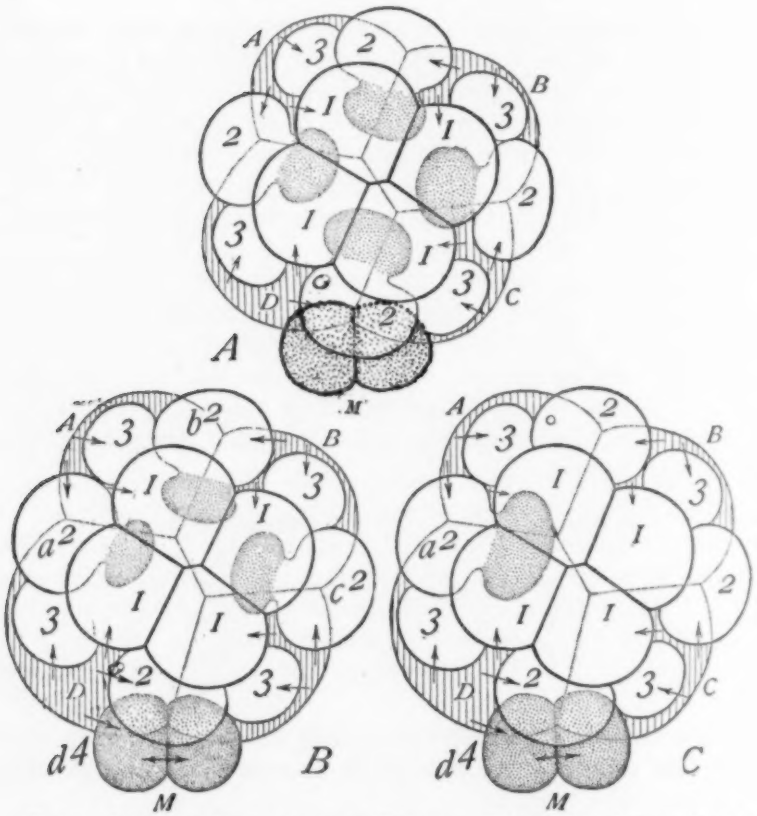


FIG. 4. ANCESTRAL REMINISCENCE IN CLEAVAGE. Showing homologous cells in *A*, a polyclade (*Leproplana*); *B*, a gasteropod (*Crepidula*); *C*, a lamellibranch (*Unio*). (Modified from Wilson.)

tional stages have been added on to those present in lower forms or that adult stages of lower animals have been crowded back into the embryonic life of higher forms as the recapitulation theory assumed. It does not mean that all organisms are alike in early stages of development and that they first become unlike in later stages. We now have direct evidence that several distinct types of animals have distinct types of eggs; thus there are the (1) Cœlenterate, (2) Polyclade-Annelid-Mollusk, (3) Echinoderm, (4) Nematode and (5) Chordate types of egg organization and these do not converge to a common type in the earliest stages of ontogeny (Fig. 6). Echinoderms come from echinoderm eggs, mollusks from mollusk eggs, vertebrates from vertebrate eggs and "the egg of a frog is as different from the egg of a hen as a frog is from a hen."

There are differences of a fundamental order, even in the earliest stages of development, between a vertebrate and an invertebrate, and the early development does not reveal the

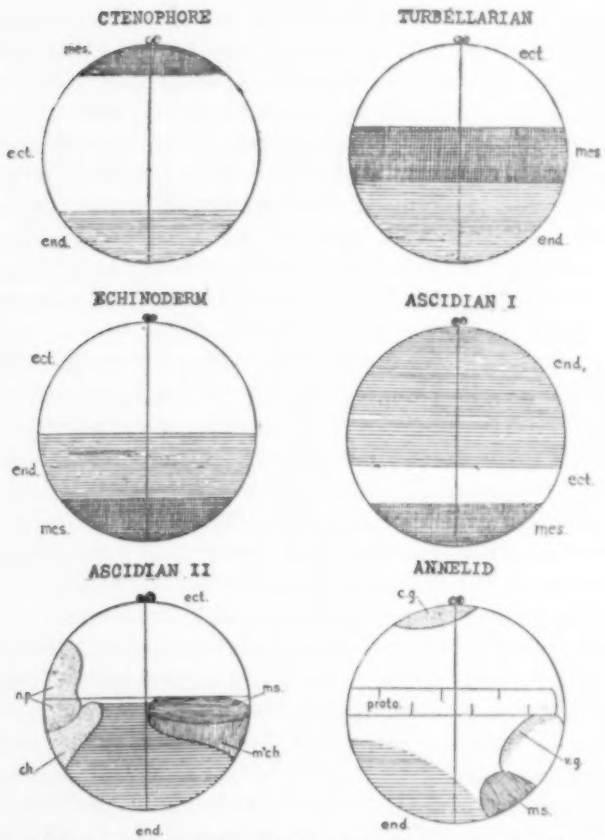


FIG. 5. TYPES OF EGG ORGANIZATION IN DIFFERENT ANIMAL PHYLA. Cross hatched area mesoderm or mesenchyme (*mes*); horizontal lines endoderm (*end*); unshaded area ectoderm (*Ect*). In the first four figures the pattern of localization is that found about the time of the first cleavage; in the last two figures the pattern is that found at a later stage; *n.p.*, neural plate; *ch.*, chorda; *c.g.*, cerebral ganglion; *v.g.*, ventral ganglion; *proto.*, prototroch.

manner in which the one may have been derived from the other. The annelids do not approach the chordates or echinoderms in the earliest stages of development any more closely than in the later stages (Fig. 6). In short there is no convergence toward a common type as one goes back to earlier and earlier stages of

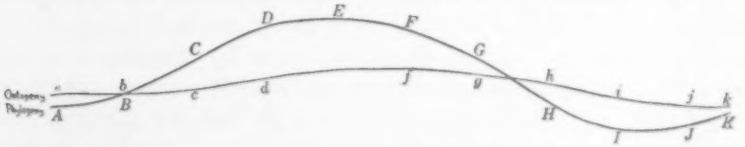


FIG. 6. DIAGRAM OF THE PARALLELISM OF ONTOGENY AND PHYLOGENY, the course of the latter being more roundabout and of the former more direct. Where ontogeny follows phylogeny most closely we have *palingenetic* stages, where it departs from phylogeny the stages are *cœnogenetic*.

ontogeny. The recapitulation theory assumes that there is such a convergence in the early stages, but on the other hand the accurate study of the "cell lineage" of eggs and embryos shows that the resemblances and differences between different animals in the earliest stages of development are of the same order of magnitude as those between later stages. Homologies of cleavage must be due to similarities in the protoplasmic organization of the cleavage cells, and the same must be said of homologies of eggs before cleavage begins. Similarities in the protoplasmic substances of eggs and in the pattern of localization must lie at the bottom of all later appearing similarities.

The cause of all embryonic homologies is therefore the same as the cause of adult homologies, viz., inherited likeness in the protoplasm due to community of descent, and it is only because there is increase of specialization as development progresses that the most general resemblances are found in the earliest stages, while more special resemblances occur only in later ones. This alone explains the fact that embryonic resemblances are on the whole more persistent than those of the adult.

(3) *Resemblances in Functions and Processes more General than in Structures.*—The stages of phylogeny are not exactly repeated in the ontogeny because all conditions both intrinsic and extrinsic are not the same, but the principles of *heredity* and *variation*, of *differentiation* and *development*, are everywhere the same in all plants and animals and men, and these principles of ontogeny are at the same time the principles of phylogeny. Ontogeny recapitulates phylogeny not in all its stages and forms, but in its *factors* and *principles*. All the fundamental principles of evolution from ameba to man are involved in the development of a single link in this long chain.

(*c*) *Inverted View of Phylogeny.*—A false trend was given also to all theories of evolution before Weismann by failing to give sufficient attention to the fact that the germ cells are the only bond between species as well as between generations. In older theories of evolution the great fact of ontogeny was neglected and it was generally assumed that one mature form underwent modification by which it was transformed into another. Adult stages of different types were compared and it was shown how one could be derived from the other by turning it upside down, by closing up the old mouth and opening a new one somewhere else, and by making other equally radical changes in a fully developed organism (Fig. 7). Ontogeny was temporarily forgotten and the fact was overlooked that mature organisms do not produce mature organisms, but that each generation arises from germ cells which alone are continuous from generation to generation.

Until recently, evolution was regarded almost entirely from the standpoint of the developed organism. The great problem of evolution was supposed to be the method by which one type of developed animal or plant gave rise to another type. Mature organisms are known to undergo changes in response to environment or to conditions of life and these changes were regarded as evolutionary ones. Thus Lamarck supposed that the numerous modifications which adult plants and animals undergo in response to conditions of climate, food, use or disuse, etc., are real evolutionary changes which convert one type into another, and even down to the present time there are many naturalists who hold the same view. Indeed many scientists who would refuse to be classified as Lamarckians, because of some minor disagreement with the views of the great French naturalist as to the cause of evolutionary changes or their method of inheritance, nevertheless hold against all opposition the *main tenet of Lamarckism, viz., that evolutionary changes are first wrought in mature organisms.* The classical illustrations of this, which were cited by Lamarck, are familiar to every one, such as the elongation of the neck and forelegs of the giraffe by attempting to reach higher leaves on trees, and the loss of limbs in snakes because of disuse in the narrow quarters in which they live. Many somewhat similar illustrations of this view that evolutionary changes first appear in adult organisms were cited by Darwin, such as the reduction or loss of wings in certain birds or the loss of eyes in cave animals, owing to disuse. More recent literature is filled with such instances; I need only refer to the opinions of many paleontologists, whose studies must of necessity be confined largely to mature organisms, that evolutionary changes take place in these

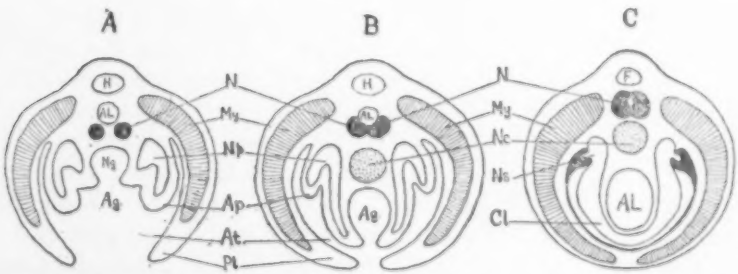


FIG. 7. DIAGRAMS OF THE SUPPOSED ORIGIN OF VERTEBRATES FROM TRILOBITE-LIKE ANCESTORS, ACCORDING TO GASKELL. Cross sections of the body of (*A*) Trilobite, (*B*) Intermediate form, (*C*) Vertebrate. The alimentary canal (*AL*) of the Trilobite becomes the neural canal (*N*) of the vertebrate, while the alimentary canal of the latter is derived from a groove on the ventral surface of the Trilobite's body (*Ag*) which is folded in to form a tube. The notochord (*Nc*) is likewise derived from a ventral groove (*Ng*) of the Trilobite's body. *H*, heart; *My*, myotome; *Np*, nephrocoel; *Ap*, appendages; *At*, atrial chamber; *Pl*, pleuron; *F*, fat body; *Cl*, coelom.

organisms by the addition of new "end stages" to those previously present; or to the views of the older anatomists that inverse symmetry, or "situs transversus," is caused by the transposition of developed organs from one side of the body to the other; or to the various theories as to the origin of vertebrates from actinians, nemerteans, annelids, arachnids or other invertebrates, by the inversion of the developed bodies of the latter and the transposition and transformation of certain organs (Fig. 7). Indeed all persons are by nature Lamarckians, and for this very reason that attention is focused upon adult organisms which are seen and known of all men rather than upon the germ cells which are usually unseen and unknown.

In all of these cases modifications of adult organisms were supposed to have brought about the changes from one species to another or from one phylum to another. The great problems of evolution were (1) to determine how these adult changes were produced and (2) to show how they were carried over or "transmitted" from one generation to the next. With regard to the last named problem it was evident that these adult changes, if they were to be handed on must be impressed in some way upon the germ cells, since the germ cells form the only living connection between successive generations. Consequently various hypotheses arose, such as were described in the previous section, to show how adult characters might be "reflected" back upon the earlier stages of ontogeny or even upon the germ cells themselves.

(*d*) *Inverted Views of Heredity or the Inheritance of Acquired Characters.*—This is what was originally meant by the phrase "inheritance of acquired characters," namely that changes in adult structures and functions are in some way impressed upon the germ cells so that these identical changes are thereafter inherited. Darwin was the first to suggest a possible mechanism for such inheritance of adult characters in his "Provisional Hypothesis of Pangenesis." He assumed that every portion, perhaps every cell, of the developed organism gave off minute living units or "gemmules" and that these gemmules accumulated in the germ cells and in the course of the development of these cells the gemmules became active and gave rise to parts or cells similar to those from which they originally came. Incredibly complex as such a process must be in normal ontogeny, it became still more complex when the attempt was made to explain the "inheritance of acquired characters," for since *ex hypothese* such characters can be acquired and reappear in offspring at any period in ontogeny it was necessary to assume that these gemmules were given off from all the cells at

every period of life. Apart from positive disproof of the hypothesis which was quickly furnished by Galton, it must have broken down from its own weight of incredible assumptions and additional hypotheses.

Since Darwin's time many attempts have been made to devise a more acceptable hypothesis to explain the mechanism of the "inheritance of acquired characters." Many of these are mere modifications of Darwin's hypothesis of pangenesis; others involve the transmission from the body to the germ cells of other, and usually more mysterious, things than gemmules. Among these are supposed "impressions," either nervous, psychic, or mnemonic, but in every instance these speculations follow Darwin's hypothesis in supposing that something proceeds from every part of the adult organism to the germ cells and so modifies those cells that in the course of their development they reproduce the very stages and changes which the adult organism first manifested. They are built on the erroneous idea that the body makes the germ cells; they represent the inverted view of development.

These hypotheses are not only pure assumptions, but in the main they have been invented to explain phenomena which are themselves pure assumptions. Thirty-five years ago Weismann boldly challenged the generally accepted doctrine that "acquired characters" *are* inherited, and from that day to this probably not a single case of such inheritance has been demonstrated, while most of the supposed cases of such inheritance could be better interpreted in some other way. Those who still believe in such inheritance are compelled to admit that it occurs very rarely and exceptionally if at all.

The older ideas of inheritance represented developed characters as being transmitted from one generation to the next; a son was said to have inherited his father's nose or his mother's eyes as if these developed characters were transmitted unchanged. But such a view entirely overlooked the facts of development; characters are never transmitted but only the germinal elements or "factors" of characters and characters develop from these only under the influence of environment, so that every developed character is due to both inheritance and environment. The distinction between inherited and acquired characters is therefore not a logical one, for every developed character is both inherited and acquired. In its original meaning, therefore, the term "inheritance of acquired characters" may be dismissed as not only illogical, but as also impossible in sexual reproduction.

Unfortunately this expression is now used not only in its

original sense but also with a very different meaning, viz., the modification of the germplasm through environmental influences, or more briefly the "inheritance of germinal modifications." Indeed the latter is all that is usually meant when the former expression is used, for few if any persons would now maintain that developed characters can enter into or impress themselves upon the germ cells so as to be born again in the next generation. On the other hand it is quite possible that environmental influences may act upon the germ cells so as to alter

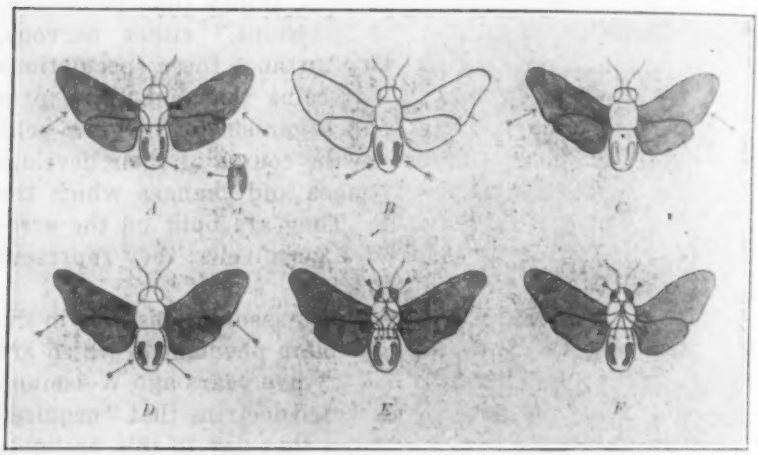


FIG. 8. DIAGRAM TO SHOW THE VARIOUS WAYS IN WHICH ENVIRONMENT MIGHT INFLUENCE THE GERM CELLS. *A*. Environment modifies the body and the latter, the germ cells so as to produce identical modifications in the next generation (*a*); this is "inheritance of acquired characters." *B*. Environment modifies the germ cells but not the body. *C*. Environment modifies the body but not the germ cells. *D*. Environment acts independently upon both body and germ cells. *E*. Environment acts through nervous system on different parts of the body which parts in turn modify the germ cells. *F*. Environment acts through nervous system upon various parts of the body and at the same time upon the germ cells.

their hereditary constitution. Whether this possibility is ever realized, whether extrinsic conditions may ever modify the germplasm so as to produce permanent changes in heredity, is the central problem of evolution.

It is conceivable that the environment may modify the germ cells in one or more of the methods shown in the accompanying diagram (Fig. 8). In A the environment is supposed to modify the body or soma, which in turn modifies the germ cells so that they produce a body modified like the parental one; this is typical inheritance of an acquired character, and it probably never takes place. In B the environment is shown acting directly upon the germ cells but not upon the body, and in C upon the body but not upon the germ cells, while in D the environment acts independently upon body and germ cells. Probably all of

the conditions shown in B, C and D actually exist but it should be noted that when germ cells are modified by environment these modifications are not identical with those of the body nor do they develop into such modified bodies; in short in these three cases there is no inheritance of acquired characters. Finally in E and F are shown two possible ways in which environment may influence the germ cells through the body; in E the environment is supposed to act through the nervous system on various parts of the body, which parts in turn act upon the germ cells; while in F there is parallel action, through the nervous system, upon various parts of the body and also upon the germ cells. There is no satisfactory evidence either for or against the conditions shown in E and F and it is possible that they as well as B, C and D may represent actual conditions. Only against the condition shown in A, that is against the inheritance of acquired characters in the original sense, is the evidence conclusive.

While it is undoubtedly true that the egg produces the hen and other eggs, and that the hen, that is the body or soma, does not *produce* the egg, it is equally true that the body of the hen, which is the environment of the ovarian egg, may *modify* the egg just as the external environment may modify the organism as a whole. But experience shows that such modifications are usually not inherited, they come and go with changing environment, they represent indeed the reactions of a relatively stable organism to an unstable environment. Least of all do these modifications of the germ or of the developed organism *resemble* the changes of the internal or external environment which called them forth; a hen with an artificially modified ovary or oviduct or thyroid gland may possibly produce a modified kind of egg, but there is no more reason for supposing that the chick into which this egg develops will show the same modification of ovary, oviduct or thyroid gland than there is for supposing that a cold climate will produce a race of cold-blooded animals or a vegetable diet a species of vegetable-like animals,—and this because the responses of a germ or of a developed organism to its environment in no way *resemble* that environment. The darkness of caves does not *produce* the blindness of the animals that live in them, much less does it modify their germ cells in such a particular way that they in turn produce blind animals; it is possible, though it has never been proven, that environmental changes may cause changes in the germplasm, but it is extremely improbable that these changes are of such a sort that they will lead, after a long process of development, to the production of just such adult characters as are adapted to the

environment which caused the germinal change. Such a view involves on the part of the germplasm such a foreknowledge of future events and contingencies as could not logically be ascribed to deity itself, and which is impossible of scientific formulation or explanation. If environment ever modifies germplasm it is safe to say that these modifications neither *resemble* the environment nor, except in rare circumstances and by chance, are they *adapted* to develop into organisms which will be fitted to that environment.

Probably germ cells may be modified by the soma within which they develop as well as by outside conditions, by internal and also external environment, but there is no justification in this fact for the claim which is often made that "adult characters are reflected" from the soma to the egg or that the environmental modifications of the parents produce identical modifications in offspring,—no evidence for the opinion that because "the parents have eaten sour grapes the children's teeth are set on edge." Further consideration of the effects of external and internal environment on germplasm will be considered in a later section.

In short, development is progressive and not retrogressive, the germ cells are descended from germ cells of the preceding generation and not from the somatic or body cells by which they are surrounded, and while these somatic cells may influence or modify the germ cells by chemical products such as enzymes and hormones and possibly also in other ways, these modifications are usually temporary and are not inherited, and, contrary to the old doctrine of "inheritance of acquired characters," they do not resemble the stimulus which called them forth nor forecast the needs of the future organism into which they will develop. Even when inherited modifications are produced in germs cells by changes in the external or internal environment these modifications may not resemble those produced in somatic cells, and in no instance is there any evidence that modifications of somatic cells are transmitted from these to the germ cells.

The Lamarckian philosophy, under whatever name it appears, is based upon a belief in vitalism or preformation; either the germ foreknows the future needs of the organism by some mysterious vitalistic power, or it is the miniature of the adult and reacts to environment in the same way as the adult does. Neither of these suppositions accords with known facts, and both are contradictory to the spirit of science, for the one makes effects determine causes rather than the reverse, while the other affirms that causes and results are identical. It will always be one of the marvels of the history of science that whole genera-

tions of more or less thoughtful men, who were more or less acquainted with the phenomena of organic development could have wandered about so long in such a stupid maze.

(*e*) *The Inverted View of Selection.*—The inverted view of development lurks in many theories where it would least be expected; not merely in the transmutation of one developed species into another, and in the inheritance of acquired characters, but also to a certain extent in selection theories, for in both artificial and natural selection it is usually assumed that evolution takes place by the elimination of developed organisms and that individuals which survive "transmit their characters" to their offspring or "produce germ cells like those from which they came." Of course no adult characters are "transmitted" to offspring and no developed organism "produces" germ cells, but apart from this criticism of the terms used, which may or may not be associated with the inverted view of development, all recent studies of heredity show that not all the different germ cells of an individual are genetically alike except when that individual is absolutely homozygous, a condition which rarely occurs among sexually reproduced organisms, so that the adult organism selected may or may not contain germ cells which are like those from which it came. Thus if the hereditary constitution of the maternal germ cell is represented by *ABC* and that of the paternal cell by *abc*, the offspring would give rise to no less than eight different types of germ cells, only one of which would be like the maternal and one like the paternal cell as is shown in the accompanying diagram:

$$\left.\begin{matrix} \text{ABC} \\ \text{a b c} \end{matrix}\right\} = \begin{matrix} \text{ABC, aBC, AbC, ABc} \\ \text{abc, Abc, aBc, abC} \end{matrix}$$

Pearl has shown that some of the conflicting results as to the influence of selection in evolution may be attributed to this fact. Consequently the selection of developed organisms in the hope of thereby isolating particular germinal types is a blind and imperfect process, though it is the only possible method of procedure, since the hereditary constitution of germ cells can not be recognized directly. Nevertheless it is necessary here also to avoid the inverted view of development involved in the assumption that a certain type of adult organism "produces" germ cells of the same type.

Furthermore the opinion that the principal activity of selection is in the elimination of developed organisms directly reverses the known facts in the case. Elimination is most severe in germ cells and embryonic stages. Where one adult is eliminated tens of embryos and thousands of germ cells are elimi-

nated. These matters will be treated more fully in the section on selection.

(*f*) *The Inverted View of Adaptation.*—Akin to these inverted views of development which put the adult before the germ, the effect before the cause, the end before the beginning, are those views of adaptation which represent needs, advantages and ends as causes of organic fitness. According to these views there is present in organisms a guiding or perfecting principle, an "entelechy," "élan vital" or other unknown cause, which leads to definite and purposive results, just as human intelligence does. It is said by certain philosophical biologists that evolution and adaptation should be looked upon from the standpoint of man, their highest product, rather than from the standpoint of the simplest organisms; evolution should be explained as the result of intelligence and purpose rather than attempt to explain intelligence and purpose as the effects of evolution. In short, according to this view, fitness, purpose and intelligence are causes rather than effects of evolution and adaptation.

But there is no sufficient evidence that even in human intelligence and purpose the usual rule of cause and effect is reversed, and there are many evidences that this is not the case. In human behavior the remembered results of many previous experiences enter as causes into future actions which may thus be directed to desired ends; human intelligence and purpose have thus been built up out of sensations, reactions and remembered experiences. Probably a similar explanation may be given of the adaptive behavior of many organisms, for if results of previous experience may be conserved to any extent in protoplasm then subsequent reactions may be explained as the result of past experience, the elimination of useless reactions and the persistence of useful ones. And in similar manner all kinds of adaptations may be explained as the result of the Darwinian principle of the elimination of the unfit and the survival of the fit. There is therefore no necessity for assuming that needs, advantages and ends serve as causes of adaptation. This inverted view of cause and effect is as unnecessary as is the inverted view of development.

On the other hand certain philosophers and biologists maintain that the responses of organisms to stimuli are always adaptive; Bergson in particular has supported this hypothesis. That there is considerable evidence in favor of such a view may seem to be proven by many well-known instances of regulation and regeneration, by many protective and preservative reactions which one finds in organisms; just as the soma usually responds to stimuli in adaptive ways, so it is maintained the germplasm

also responds adaptively. However, Darwin and many others have shown conclusively that somatic responses are not always adaptive and that those which are such vary greatly in degree of perfection. That every change in the germplasm is an adaptive change to the environmental stimulus which called it forth is a thesis impossible to maintain, as is demonstrated by all recent work on mutations. Most of these mutations are positively injurious and do not in any degree make the organism better adapted to the conditions in which they arose. Furthermore it should be noted that the assumption that germplasm may respond adaptively to external stimuli really signifies that the germplasm responds in such a way that the developed organism to which it gives rise is better adapted to the environment and not that the germplasm itself is better adapted; therefore if such beneficial responses really occurred they would be beneficial only in an anticipatory way and they would be beneficial to the germplasm only secondarily and very indirectly. This hypothesis also is based upon the inverted view of development, namely, that developed organisms create and control the germplasm rather than the reverse. The fact is that there is no evidence that either germplasm or somatoplasm always responds to the environment in a directly beneficial way. The usual beneficial character of responses must be explained in some other manner.

In conclusion, all hypotheses which assume that evolutionary changes first occur in developed organisms and are then "impressed" in some manner upon the germ cells neglect entirely the well-known fact that development is not a reversible process; a man can not enter a second time into his mother's womb and be born again and a developed organism can not again become an egg. Consequently all such hypotheses not only put the cart before the horse, but they put the end of the journey before its beginning. It is now plainly apparent to those who have considered the problem of evolution most seriously that evolution must take place by modifications of germ cells or of germplasm rather than of adult organisms. Consequently all the older theories of evolution and many of the newer ones which are based upon that ancient and erroneous idea that the hen produces the egg and not the egg the hen may be dismissed without further consideration here. They represent an untenable and inverted view of organic development, for while it is absolutely certain that the fertilized egg produces the developed organism it is equally certain that the latter does not produce the former, but that every germ cell comes in direct lineage from the germ cells of the preceding generation.

(To be continued)

OUR UNIVERSE OF STARS

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THE observer who stands out under the heavens on any clear, moonless night will see the light of far distant suns shining upon him in whatever direction he may turn. If he is fortunate enough to be so far away from artificial lights, and in so clear an atmosphere that the background of the sky is nearly black, the stars that surround him seem almost innumerable. He knows that all of these are great suns, many of them far hotter and brighter than our own sun, and that the nearest is so far away that its light has spent several years in coming to him, although light travels with the enormous speed of 186,330 miles a second. It can not be long before there comes to him some realization of the immensity of the great cloud of suns in which we are immersed.

Most striking and interesting of all to the naked eye is the Milky Way, that

> Broad and ample road whose dust is gold,

so very bright and narrow in Cassiopeia, but much wider in Cygnus, where begins that most remarkable feature known as the Great Bifurcation. Here the Milky Way branches into two parts. The western branch is the brighter until Aquila is reached, where it diverges still farther to the west, and comes almost completely to an end in Ophiuchus, to begin again in Scorpius. The eastern branch meanwhile grows narrower and remains bright, until it passes below the ground in the south. Between Aquila and the horizon is the most irregular region of the entire structure. Here suns are heaped together into great clouds which alternate with faint, or almost absolutely vacant, spaces.

When a great telescope is turned in any direction, the field of view is filled with stars, which become more densely packed together as the Milky Way is approached; indeed there are parts of this which can not be resolved into separate stars, even with the most powerful optical aid. And when a delicate photographic plate is exposed for many hours to any part of the heavens, the images of continually fainter and fainter stars appear upon it, until a record is secured of objects far too faint to be seen in any telescope. There are also revealed innumer-

able additional star-clouds and star-clusters, double and variable stars, and, in short, all of the objects the study of which makes up modern sidereal astronomy.

Evidently, the star cloud which surrounds us is of almost infinite complexity. It is no wonder that Sir William Herschel, its first explorer, became wholly absorbed in his work, and that his devoted sister, Caroline, sat, night after night, recording his observations until her feet were frozen to the ground. Not only did Herschel describe and catalogue for the first time thousands of double stars, nebulas, and other objects, but he sought to get some approximation to the form of the cloud of suns of which we are a part. This he did by counting vast numbers of stars seen in different directions and assuming that the relative distances of the stars could be found from their comparative brightness; that the fainter stars, on the whole, appeared faint only on account of their great distances from us. Thus he reached the conclusion that our universe has roughly the form of a grindstone, the greatest dimension lying in the direction of the Milky Way, and our sun being near the center.

But unfortunately, this assumption of Herschel with regard to the fainter stars can only very roughly be said to be true. We now know that the faint and bright stars are inextricably mixed in our star cloud; some of the nearest stars of the heavens are very faint and some of the brightest are so far away that their distances can not be directly measured. In addition to this, the surprising fact appears that the distribution of the stars depends to a large extent upon their comparative development. Those but little advanced from a nebulous stage congregate strongly in the direction of the Milky Way; those which have proceeded farther in their development surround us in a much less flattened cloud.

Taken as a whole, we now know that our Milky Way cloud of stars, though inconceivably vast, is far from being of infinite extent. It is also of a much more complex structure than described by Herschel. The stars of our visible universe are arranged in a flattened, lens-shaped form, the least distance through which is perhaps 2,000 light years, and of which the greatest diameter, extending in the direction of the Milky Way, is possibly four times as great. To a distance of about 300 light years in every direction, the distribution of the stars is nearly uniform. Beyond this the numbers rapidly fall off, until at a distance of 1,000 light years in the direction of the Poles of the Milky Way, the density is diminished to perhaps one fifth of that at the center. Around the edge of the great disc are the irregular clouds of the Milky Way, the inner edge of the nearest of which is perhaps 4,000 light years from us. Some astrono-

mers believe that there is an almost vacant space between the stars of our inner, flattened cloud and the complicated structure which surrounds it.

The individual suns which make up this complex cloud were, until very recently, believed to be moving indifferently in every direction, and in regard to a majority of them this is still believed to be true. But the surprising discovery was recently made that many of the stars belong to two great streams moving in both directions along a line which lies in the place of the Milky Way. There are thus two streams, the stars of which move in exactly opposite directions; one stream is not in front of the other, but they inter-penetrate one another in all parts of the heavens.

We can not yet definitely account for this great streaming of the stars. Dr. H. H. Turner has suggested that it may be explained by supposing that the stars of our universe move in very large but narrow orbits about the gravitational center of our cloud and that we view them going and returning from that center, from which our own sun is at a considerable distance. The strongest objection to this theory is that it requires too strong a congestion of stars near the center. While it is possible to suppose that one of the dense patches of stars in the Milky Way is the actually congested center of our stellar system, until much more data have been accumulated it will not be possible to come to any decision in regard to the theory.

All that has been said thus far is based on a study of the bright objects of our universe, those which can be seen in the telescope or which appear after a long exposure on a delicate photographic plate. But is all, or even a large proportion, of the matter in our universe gathered into self-luminous bodies? May there not be vast quantities which, like the meteorites and shooting stars which continually fall on our earth, are dark and so invisible to us? And may not the whole cloud be filled with a cosmic dust whose mass may far exceed the combined masses of all the brighter stars? If so, the gravitational pull of this diffused matter becomes of dominant importance in any inquiry into the future development of our system.

Fortunately, if the space within our star cloud is filled with finely divided matter, not only will the light from far distant suns be rendered fainter, but it will also be reddened in color. The reddening effect of a fine dust was very noticeable 36 years ago, when all of the air about the earth was filled with dust from an eruption of the great volcano, Krakatoa. This was a time of intensely red sunrises and sunsets which persisted for more than a year until, after the slow settling down of the dust particles, the air was again comparatively clean.

Thus, if finely divided matter exists in inter-stellar space, the more distant stars will be distinctly reddened. If a large number of stars known, or believed to be, very distant are arranged in a series according to their color, there will be a larger proportion of red stars than there are among those in the vicinity of our sun. Moreover, very blue stars will not be seen.

Studies based on this change of color have been carefully made by several observers, but the observations are very difficult and the results are discordant; the largest of the modern results is nearly three times the smallest. An average of the three best determinations indicated, however, that there is the equivalent of about 50,000 hydrogen molecules in each cubic centimeter of space. This is, of course, very far beyond the most perfect vacuum which we can attain artificially, and it would probably have no appreciable effect on the motion of the planets, but in a study of the development of our universe its effect becomes very important. For the total mass of this material would be no less than 150,000 times the estimated mass of all the stars in any large region of space.

An apparently more reasonable conclusion was reached three years ago by Dr. Harlow Shapley, of the Mount Wilson Solar Observatory, from a study of the bright cluster of stars in Hercules, and several other spherical clusters. This is the brightest star cluster visible to northern observers; it is almost overhead in the early evenings of July, and indeed is in excellent position for observation throughout the summer. In this wonderful aggregation of suns, more than 50,000 separate stars have been counted, down to the twenty-first magnitude, and the whole number must be vastly greater than this. The Hercules cluster is very remote from us; its distance is so great that the light of its stars occupies some 30,000 years in coming to us. Thus, it is wholly beyond the borders of our Milky Way universe.

Now when the stars of this very distant cluster are examined in regard to their color it is found that their distribution is almost indistinguishable from that of the stars which are near our sun. So little is this alteration that it is found to correspond to an extinction of but one per cent. of the intensity of a ray of light in travelling through space for 3,000 years.

From thirteen clusters examined in this way, Dr. Shapley has obtained practically identical results. As these objects lie in all different directions from us, the transparency of space is thus tested in these many directions. In each of them the amount of cosmic dust is found to be so small as to be almost negligible.

Inter-stellar space is, so far as cosmic dust goes, very clean. But there may be dark stars and dark nebulas in our star cloud

whose only effect is to cut off the light of whatever is beyond them. Of this nature, probably, are some of the dark spaces in the Milky Way, recently photographed and discussed by Dr. E. E. Barnard. No one can doubt that in some of these beautiful photographs we see the distant clouds of stars partially hidden by dark matter in front of them. But this opaque matter is very local. In general, there is no evidence of any dark material between us and the distant stars. We are therefore justified in estimating its total amount as but small compared with the whole mass of the stars.

If we therefore suppose that there is not an excessive amount of dark matter in our universe, we may proceed to inquire how the form of our star cloud will change under the action of the bright bodies which compose it. And it may be remarked that even if we assume the mass of dark matter as equal to, or even greater, than that of matter visible to us, the general character of our conclusions will not be altered.

But at the very outset we must decide between two wholly different modes of investigation. Until very recently it was believed that the stars can be compared to the molecules of a gas and that the laws applied in the theory of gases can be equally applied to our cloud of stars. These laws depend very largely upon the incessant collision and rebound of the gaseous molecules, by which the energy of motion is communicated from one to the other. Do the stars pass close to one another frequently enough (for actual collision is not necessary here), to make the kinetic theory of gases applicable, or are their close approaches relatively so infrequent that the gravitational pull of all of the stars of the cloud is all that need be considered?

Some light is thrown on this question by the quite recent discovery of several clusters of stars, ploughing directly through the cloud of stars which surrounds us. Perhaps the best known of these, and the one which has been most fully investigated, is the moving cluster in Taurus. This is a group of 41 bright stars, scattered over the whole western half of the constellation, though mostly concentrated about the Hyades, a study of whose motions shows that they are moving together through our star cloud. They are all moving in perfectly parallel lines with a speed of 28 miles a second. They, in fact, make up a globular star cluster, about 35 light years in diameter; this passed nearest us about 800,000 years ago; when viewed from the earth at this time the individual stars seemed even more scattered than at present. In 65,000,000 years the group will appear as a little round cluster of faint stars, five eighths the diameter of the full moon.

As we know the distance away of this cluster, it is easy to

find the absolute brightness of each of its stars. It is interesting to note that they are all far more luminous than our sun, the brightest ones exceeding the brightness of our sun by nearly 100 times. In the neighborhood of our sun we have nothing to compare with this brilliant assemblage of stars. Perhaps there are many fainter stars within the borders of the cluster, and belonging to it, but the motions of the fainter stars have not yet been so studied as to enable us to decide this point.

A second, very celebrated, cluster is known as the Ursa Major system because all of the stars of the Great Dipper are known to belong to it except the two extreme ones. It also includes the brightest star of the delicate little constellation of the Northern Crown and the very brilliant Dog Star, Sirius. This is a very flattened, disc-shaped cluster with an extreme diameter of about 110 light years; its thickness is only 8 light years. This cluster is moving somewhat more slowly than the cluster in Taurus, its speed being but 18 miles a second. All of its stars are far brighter than the sun.

Several other moving clusters are known. For our purposes, the striking fact to be noticed in connection with them is that though each one moves through the star cloud so that innumerable stars, distinct from the cluster, must be enveloped by it and afterward left behind as the swarm moves on, yet the stars of the cluster continue to move with an unchanged velocity and in parallel lines. It appears that even in these exceptional cases the chance near approach of two stars is a very unusual occurrence.

It is true that M. C. V. L. Charlier and other astronomers, who believe that the effects of near approaches should be taken into account, suppose that the stars remaining in the cluster are an insignificant remnant of a far greater swarm, most of whose members have been deflected by the stars of our cloud, and so driven away. But if this is so, it seems improbable that those which remain should have absolutely parallel and common motions. It seems more reasonable to suppose that from an original great swarm there should ensue all imaginable deflections from parallelism, from the slightest to those so great that the corresponding members have been driven out of the system altogether.

When, therefore, we consider the phenomena of moving clusters, and think too of the great distances which separate the stars, the evidence seems conclusive that the effects of occasional collisions may be altogether neglected. We need only consider the effects of the general gravitational attraction of the whole cloud of stars, and the kinetic theory of gases may be discarded in this connection.

But even with this restriction the problem is a very difficult one, calling for a development of the science of dynamics beyond any as yet available. However, certain general conclusions can be reached, even if the details can not be as yet filled in.

Whether we consider the kinetic theory of gases as applicable, or not, it appears that our universe is far from a form in which equilibrium can exist. It is in a state of rapid collapse. It may, under the gravitational pull of each of its suns, reach a condition of approximate equilibrium in 1,000,000,000 years. For an almost complete equilibrium, a duration 1,000 times as long is required. And under the kinetic theory, the times are about 100,000 times as great as these. At the expiration of these inconceivably great times, our cloud will probably be found of an approximately spherical form.

An interesting question here arises as to whether each star of our cloud will not have gone through its life long before these changes shall be consummated. Whether each of the bright stars will not have become cold and dark, ages upon ages before that remote time, and whether, if there are then any bright bodies in the universe, they will not be new stars, different from those we see now. For, according to the classic theory of Helmholtz, the life of a sun is a comparatively short one. This theory assumes that all of the heat radiated by a sun into space is caused by the slow contraction of the radiating body; every portion of the mass in thus falling toward the center loses its energy of position, which is transformed into heat energy and radiated away. It is a very simple matter to compute the past and future duration of our sun, for example, supposing that all of its heat is due to this source and that its radiation has remained sensibly constant. It is found that it could not have given off heat at its present rate for more than about 30,000,000 years, and that in 7,000,000 years from now it will have shrunk to one half its present radius; its increasing density will then probably cause its shrinking to be very much slower, and its heat and light will also begin to rapidly decrease.

But from geological considerations a much longer time is wanted. From a physical discussion alone, Sir George Darwin considered that "500 to 1,000 millions of years may have elapsed since the birth of the moon," and Dr. John Perry states that "if the paleontologists have good reasons for demanding greater times, I see nothing from the physicist's point of view which denies them four times the greatest of these estimates." And the paleontologists ask for a very long time to reasonably account for the grand upward development of life upon our earth. For many years it has been indeed evident that the contraction theory of Helmholtz is inadequate. Not that the con-

traction of the sun is not a true source of heat, and this cause must be ever in operation, but a greater source of energy must be looked for. And this, it is now thought, may be found in the atom.

During the past two decades, modern physicists have gotten very far away from the "small, round, smooth atoms" of Democritus. We know now that the atom is a very complex thing. With so-called radio-active substances it may be broken up, with the liberation of an immense amount of energy, the newer elements which result from the process having lower atomic weights than the original substance. Whether an appreciable amount of the heat and other energy emitted by the sun is of this sub-atomic origin, we do not know, but it seems not unreasonable to suppose that it is. For we can not even approximate to conditions as they must be found within the solar globe. It is true that the average temperature of the outside surface of the sun probably does not far exceed 12,000° Fahrenheit, but how very much hotter it is in the interior we have no means of knowing. The pressures, too, within the ball of the sun, are enormous. A very simple computation shows that at the depth of only 1,000 miles below the surface the pressure is nearly 6,000,000 tons on each square foot, an amount, of course, which we are wholly unable even to approach in our laboratories. It seems very probable that when subjected to these inconceivably great temperatures and pressures, atoms may be broken up, and a part, at least, of their sub-atomic energy may be liberated. And it is only necessary to suppose that a part of the energy of the atom is in this way radiated into space in order that the life of a sun, or star, may be almost indefinitely prolonged.

A rough image of the form which our stellar universe will take in the very remote ages of the future is furnished by those beautiful objects, the spherical, or globular, clusters of stars. The remarkable work of Shapley has shown that these are on the borders or wholly beyond the limits of our star cloud. They are isolated in space, and from probably irregular clouds have slowly taken the spherical form under the mutual pull of all of their stars. They are much smaller than our universe; the distance through them is measured in hundreds, instead of in tens of thousands of light years; they have therefore gone through their development much more rapidly. But it is very probable that our own far greater system will take approximately this same form, after a time so long that all times hitherto considered in astronomy shrink almost to nothing in comparison.

INDIVIDUALITY IN RESEARCH

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THE men of no other country have exhibited so great a measure of individuality in research as those of England. In the highest degree they have manifested the self-reliant strength of natural genius. Among them scientific endeavor has not been organized; and for the most part investigations have been carried out by single workers in isolation. British science has always refrained from congregating in distinct schools and institutions; it has never been localized in definite centers. No compact body of pupils there develops the work and ideas of any master. Thinkers proceed singly and individually with their self-appointed tasks laboring in close touch with nature and according to their particular inclinations.

These peculiarities of British science have always been in evidence from the earliest times through the central achievements of Newton and down to our own day. In illustration of the way of work of a scientist in England let us consider the contributions of Faraday, through whose labors the theory of electricity has been revolutionized. Guided by his own experimental researches, which resulted in the knowledge of many new facts and opened up problems of far-reaching importance, he developed his own mental construct or individual way of representing the phenomena to his thought which was so far different from that employed by others that only a few in a generation were able to follow him in the course of his reasoning. He pictured space in the neighborhood of an electric charge as filled with lines of electric force and through these lines found a means of penetrating to a deeper understanding of electric phenomena than any of his predecessors or contemporaries. By aid of an active imagination he was able to ascertain the nature of the interactions among electric charges, representing these to himself by means of geometric relations among his innumerable curved lines of force.

For a time it seemed to most interested persons that his processes were too loose to permit of confidence in his conclusions; though all admitted that they had led him into the most interesting and remarkable experimental researches. After the

matter had lain for a time in this state in which the theoretical explanations had so large an element of individual bias in them that they could not be understood by most investigators, the entire theory was taken up anew by Maxwell in the light of Faraday's speculative discussions and reduced to a new mathematical form. In this way it finally became clear that Faraday's original conceptions had in them all the clarity of mathematical precision.

But it was the next generation after Faraday which first understood properly the range of his ideas. So is it likely to be ever with thinkers of the most marked individuality; so has it been preeminently among British scientists. As another example witness the case of Newton, whose work was first thoroughly appreciated by the following generation and in another country than his own.

In this respect the English are in most pronounced opposition to the Germans, while in some ways the French occupy the intermediate ground between them. Of these three countries which have led in scientific development it seems to be the impartial verdict of history that we owe to France the largest number of works perfect in form and substance and classical for all time; that the greatest bulk of scientific work, at least in more recent years, has been produced in Germany; but that the new ideas which have fructified science, in earlier times and also in the nineteenth century, have arisen more frequently in England than in any other country. In the second half of the nineteenth century the three leading ideas of science were probably the law of conservation of energy, Darwin's theory of descent, and Faraday's conception of electrical phenomena particularly in the more generally intelligible form which Maxwell gave to it. The latter two of these arose definitely in England; and the work of Joule on heat went a long way toward the fuller announcement of the first by Helmholtz. All three of them have been worked out with the definite cooperation of scientific investigators in all countries.

At the beginning of the nineteenth century the spirit of exact science, so far as it belonged to any large portion of the educated population, was domiciled in Paris. In such an atmosphere scientific writings took on the form of elegant literary productions. From Paris the spirit of interest spread into all countries and leavened the thought and literature of the whole world. In the country of its origin this elegant literature has maintained the traditions of its early development. In England it has been modified by the spirit which magnifies the individu-

ality of each thinker. In Germany it has taken the direction indicated by the great organization of thought there. Most German investigators stand under the guidance of a few leading minds. Their contributions to thought fall, therefore, into a few important schools in which all their researches may be ordered.

To this general statement there is one marked exception. At least one of the great intellects of Germany worked in isolation very much like that which forms the rule in England; and it is worthy of note that he is without question the greatest man in his field produced in Germany and in every respect one of the foremost men of thought in the world. I refer to Gauss, the self-taught mathematician, a thinker whose work was not well understood and appreciated by his contemporaries. But the one notable exception leaves intact the general rule that the spirit of investigation in Germany has generally manifested itself in the labors of organized bodies of researchers.

The observation of such definite national differences, particularly that between England and Germany, brings forcibly to our attention the question as to the outward circumstances under which scientific investigation will flourish best, especially for extensive periods of time or in the long run. The two kinds of activity, that in which the workers are joined together in more or less compact bodies each of which is engaged in developing one general class of ideas and that in which the individual researchers labor in isolation pursuing separately their several inclinations, presumably have their characteristic advantages and defects. To know what these are is a matter of importance both to the nation and to the individual investigator.

Let us suppose that a particular science is in the situation of having its main general ideas already at hand and that it is confronted with their detailed development as the work next to be considered. It is clear that this is a situation in which organization of effort is going to count for efficiency. It is then relatively easy for a man of initiative to direct the researches of several less gifted collaborators. A number of investigators thus working together in unity instead of isolation afford much assistance and stimulation to each other and accomplish in a short time what otherwise would require a much longer period.

In a condition of this sort German science in recent years has been far more efficient than that of any other country, while of the four or five leading nations England has probably profited least by organization of effort. In British science generally we are struck by two things: the individual greatness

of certain separate investigators, and the meager results achieved by all others. But in Germany we see everywhere the detailed development of particular theories and the accumulation of large masses of published results, greater in body than that produced in any other country, while in France and Italy and America we find a state of things intermediate between the extremes represented by Germany and England.

Organization of effort has advantages aptly illustrated by the achievements of German science. But there is at least a reasonable question whether it may not also have its drawbacks, whether there is not a measure or type of organization that hinders individuality and inhibits original ideas or points of view.

To some thinkers it has seemed that rare combinations of insight and perseverance and the skill to penetrate to the heart of nature are more likely to spring up among a people opposed to highly developed systems of thought and organizations of effort and given much to emphasizing the individual and his separate achievements. Such an idea seems to be borne out by the continued fruitfulness of England through many generations in the production of fundamental and guiding ideas in the development of science, particularly since she has in this respect apparently surpassed every other country.

Discoveries in England emanate most frequently from the depth of original genius in intimate communion with nature. Such a thinker is far enough separated from others to allow nature to work out her own impression upon him, so to speak, with less interference from the inertia due to fixed habits of thought and the preconceptions of contemporary science. There is no large university system in England eager to nurse and develop new talent and engulf all its energy into the common whirlpool; and English thinkers, therefore, in greater proportion than those of other countries, live in intimate communion with nature. They are thus the most likely of all to develop the new idea of fundamental importance.

Openness and plasticity of mind, even to age, is a general characteristic of men of genius. A desire for truth is their fundamental possession and they are not deterred from its pursuit by petty inconsistencies. Socrates was delighted when confuting others; and, if found in error, was no less pleased when confuted. In his mind no evil was so great as a false judgment concerning the just and the unjust.

Radical changes of opinion have not infrequently taken place in the gifted man late in life. At forty-seven years of

age Dryden in 1678 produced "All for Love," writing the play for himself rather than for the public and basing it on a new dramatic theory which he had evolved during an interval of rest from writing. Cayley turned to the study of law at twenty-five and after entering upon its practice changed his field of activity to become one of the great mathematicians. Not till the age of forty-nine did Cowper find out that he could write, and then for a time produced volume after volume which his readers have learned to dwell on with affectionate appreciation.

In genius there is nothing static. In every aspect it is dynamic. Thought is not fixed; it is in constant ebb and flow. Everything is afloat and no conservatism is safe. The talk of a man true to his individuality tears from its moorings all thought among his associates. However well things may have been set up before he speaks, they need to be set up again afterwards.

Truth-bearing ships may not rest at anchor where a genius is present; they must go forth upon voyages to the outermost bounds of thought. Inoculated with the ferment of his mind, they will deliver new and powerful knowledge in the remote regions, kindling everywhere a fresh illumination of beauty. In their moving hither and thither will be much profit of valuable exchange. The bread of life shall they bear to the needy, and return the wine of new truth to the out-sender.

In a few individual cases genius has seemed to be almost universal. Aristotle was learned in all the lore of his time and made fundamental contributions to thought in many directions. Poincaré was a leading investigator in every division of mathematics at a time when the subject was generally esteemed so vast and diverse in its parts that no man could be properly acquainted with all of its essential developments.

At the opposite extreme there have been men of high achievement in a narrow channel of activity whose work was magnificent in its proper region, but out of it was stupid. With the heroic meter Pope was a dexterous genius, but outside of his habitual forms he was helpless and indeed even insensible of his incapacity.

Among men of research this is the day of narrow specialization. Numerous workers achieve notable advancement in a narrow field and yet are not broad enough in view to estimate properly the bearings of their own results. They can do a work of value only because a greater mind has dealt with the whole problem and has made apparent the need of development

in certain phases. Research will never be able to dispense with the man of wide outlook who must do the fundamental work in the advancement of knowledge.

In the earlier days much of the activity of genius was demanded for war and government. The Roman temple of Janus, which was open during war and closed during peace, was shut only four times before the Christian era. But war with occasional peace among the ancients has given place among the moderns to peace with occasional war. For a generation prior to the Great War in Europe the activity of genius had been largely liberated for use in science. Coincident with this liberation was the most wonderful development of knowledge yet witnessed in the world. Man obtained a greatly increased control over nature and her forces; and the rapidity with which he extended his conquests far exceeded the highest expectations. Let society release anew her men of genius to pursue undisturbed each the matter of his own delights; and they will soon come again bearing the booty of peace and the rewards of thought, enriching life with enduring conquests of surprising grandeur.

Only one other period in the history of the world can be compared in its enormous advances in thought with the period of the present, namely, the age of Pericles in ancient Greece. The earlier period was characterized by the astonishing concentration of the wonderful development in the single city of Athens; the later period by the widespread advances in both Europe and America, depending on a collaboration of effort and unity of interest not before manifested in the history of thought. But these two developments, widely separated as they are in time and springing up under different world conditions, have this common element that they arose during a period of peace when genius was released from the concerns of war and was free to pursue its own more congenial interests.

Within the last one hundred years scientific research has opened up many new types of problems. It has found out how to reach with observation and measurement large classes of phenomena more intricate than any which were witnessed or even suspected in earlier times. It has sought by new methods the more hidden forces and conditions which make up and govern our everyday life. It can hardly be supposed that the science of one or two generations has found the best interpretation or explanation of all these facts, especially since relatively so few persons have been able to live in intimate daily com-

munion with these novel and till recently hidden aspects of nature.

It seems therefore that this is an age which, while not neglecting the development of detailed results, is peculiarly one that should look with favor upon deep individuality and the consecration of the man possessing it to a life of intimate and daily communion with phenomena—a communion in which, as far as possible, he shall let nature speak her own language to him in her simplicity and unimpeded by the foreign accent and construction of our scientific jargon. It appears that in this way one has the best expectation of coming to a new and more penetrating vision.

In order that our research into nature shall be most effective in the long run it seems therefore to be a matter of the highest concern to keep unimpaired the deep individuality of those who live much alone with the intricate phenomena of the new nature revealed to us by contemporary observation. The continual presence of such spirits upon the planet affords the highest blessing which it can receive.

This interaction of individuality and organization presents a threefold aspect, appearing in its relation to the whole world of thought, to the activity of a single nation, and to the plans and purposes of the individual. Perhaps the problem for the world at large is best solved by that partial national division of labor which has existed heretofore and which is exhibited in a most marked manner by the contrasts of German and English scientific work. To the individual, particularly to the young researcher just finding himself and his most suitable field of interest, the problem appears in a somewhat different light.

For him the question often presents itself in this way: In a range of ideas already marked by the individuality of another and being worked out in detail from a well-defined point of view he sees a number of problems which interest him and into the solution of which he could go with zest and enthusiasm; but he sees that, for the present at least, this would be to merge his individuality in that of his predecessor. On the other hand, he may see or may desire to seek less well-defined fields of investigation which are awaiting the impress of a new individuality to bring to life their dormant possibilities. Into one of these he may enter and reduce to order, slowly at first and more rapidly afterwards, the chaos which he finds there. The first procedure will usually bring him into earlier notice; for among those ideas which are well-defined and those problems which are clearly set he will the more readily penetrate beyond

the boundaries of present knowledge. But if he starts in the latter direction, though he may move things less promptly he will push them much further if he succeeds at all in getting them effectively into motion.

The more a domain demands originality for its exploration, the fewer are those individuals whose courage and persistence will enable them to penetrate it. It is better for a man to do the smaller work well than to fail entirely at the larger; but it is a more profound tragedy if the man of higher force does not find himself and therefore never applies himself to the greater problems which he might solve.

Thus the young researcher is confronted with a situation potent in its influence upon his life and the value to mankind of his labors; and between the two possibilities he must choose, either consciously and with foresight or unconsciously under the force of circumstances. Let him remember that the choice is to be made in the light of the character of service which his life devotion to constructive thought is to render in the progress of mankind.

The work of highest value can be done only as an expression of the most marked individuality. Let the beginner keep this ever before him as a fundamental principle. If his achievement is to have any first-rate qualities it must be through his allowing nature to write herself into his thought unimpeded by preconception, however hidden. The Universe honors nothing so much as the man who stands on his feet without the prop of contemporary or predecessor; and to no one else are her secrets so readily revealed. Every young researcher must choose for himself whether he shall stand in the place to receive this greater illumination or enter upon the less inspiring labor of developing already existent ideas.

The man of highest genius respects his work and does it nobly not only because it is of great value to mankind but also for a reason more important to him individually, namely, that it is an expression of himself and a means of developing him into that which he should become. He does not compare it with that of others as to value. It is a thing to stand alone and be judged of itself. With him is no concern for greater or less of genuine achievement. A realization of the best that is in him is all that he can accomplish; and he is unwilling to do what is less or different. The past and the distant, the near and the contemporary, delight him as commentaries on his own experience; but for himself he seeks primarily the noblest self-expression, whether in the production of art or in

the creation of scientific truth. When a country does not find its ideals at home but draws them from abroad, it builds nothing worthy of admiration or study. When an institution, as of learning, looks elsewhere for its inspiration and not to its own men and environment, it is dead and can not lead or inspire in the way of knowledge. When an individual draws his problem from another individual he has already made himself of second rate or lower in research. But when a man takes up a problem that appeals to him or an institution plans a work which grows out of its place in its environment or a country according to its circumstances builds up what interests its own people, each does a work of fundamental import and becomes a source of instruction and inspiration to mankind.

The greatest need of every generation in science is the man who knows current theories and tendencies and yet thinks from a center of his own, the course of whose activity is spontaneous and free as the flow of a rivulet, adjusting itself with as little effort to the inhibiting bounds of his environment. He is the perennial fountain of life and power. Primarily he is concerned not with the impressions which things make on the minds of other men, but with what they make on his own. He gives place to the opinions of others only as a sort of commentary on his own thought, as the scholar's annotations are intended to elucidate the meaning of the master in the text. His business is not to declaim on the beauties which others have attained to, but to find a new and deeper beauty underlying them, to come a little nearer to the marvelous processes of nature.

Every one transfers something of himself into his perception of the matter. If he should give an accurate account even of his most unbiased observation he would not say, It was so and so; but, rather, Thus it appeared to me. However fully preconceptions and prejudices are laid aside, there is one thing unrelated to the event which the observer can not put away, namely, the observer himself. If one is sincere and thinks from a center of his own, everything will take somewhat the color of the beholding eye, just as the world appears red when seen through red glasses.

It is impossible for one to come to the study of any class of phenomena or range of ideas without bringing his past experience and the inertia of his previous way of looking at things. Even natural science has found no way to avoid this. At best one can only reduce to a minimum the influence of prejudice and the inertia of preconception.

This obtrusion of the individual into every result of observation and thought has the most intimate connection with the meaning which should be attached to scientific truth and research. The characteristics of human thought and human sense impressions determine science quite as much as the external phenomena which are being studied. We possess a small number of special senses quite limited in the range of *quality* of impressions which they can give to us. Any particular one of these special sense organs, whatever the source of the stimulus, gives to us the same quality of sensation. Through the optic nerve, for instance, however it may be excited, we receive only sensations of light. Now it can hardly be supposed that nature possesses just a few qualities and those alone which we are able to perceive. Moreover, we know definitely that a single sense can not distinguish in many cases between phenomena of the most diverse kinds. Is it not then reasonable to conceive the possibility that phenomena in general exhibit many aspects, intrinsically very different, which we are not in the least able to distinguish even with the use of all our special senses? If this be true our science must in the end be very remote from the actually existent phenomena which we seek to explain. In other words, all our scientific hypotheses must be shot through in all directions by the peculiarities of the mental constitution of those who build up this science. Thus the latter is deeply colored not merely by individual, but by racial characteristics.

In all this is no cause for regret. We build our science for its value to us in ways both utilitarian and esthetic. For this it is quite sufficient for us to ascertain merely the invariant and permanent elements of the impressions made by phenomena upon the total human organism. Our progress will be greatest when we come in our explanations as closely as possible to the way in which the new phenomena would impress one who suffered least from the inertia of preconception. In other words, our progress will be most fundamental, other things being equal, when many individual researchers are moved primarily by that interest which springs from deep individuality. In this way we will have most consistent attention to the problems which lie closest to hand.

To consider first and primarily the problem nearest to hand is a concern not merely of the individual. In our country, particularly, scientific investigation carried on largely by groups of men connected with the institutions as such should develop in some measure the matters which are suggested naturally by

their relations to the varying bodies of supporters. In like manner the country as a whole should find some problems of central importance pertaining to the national life and thought in a way not in evidence elsewhere.

In the state university particularly we should find a zeal for research pertaining directly to the interests of the commonwealth supporting it. This should not take a too narrow form and would lose ultimately if it did; but it might well be adapted in a broad way to the demands of local interest.

This, however, could not affect all departments of thought; for some are essentially universal and non-local in character. Moreover, it should not be allowed to dominate all elements of thought in any department. This would be a narrowness fatal to the best interests. But in every department of most institutions (if not all) it is probably desirable to bring about the development of a local atmosphere, so to speak, favorable to concentrated effort along certain lines, but of course not antagonistic to any general trend of progress. No department in any one university can well represent every phase of the development of its subject; but it can represent a proper variety and at the same time a certain measure of continuity and deep relation of the particular fields primarily developed by it. In some cases at present our institutions are losing by too much separateness of effort in a particular environment, sometimes going so far that creative men in the same department are unable to understand the character of work produced by each other. It seems that such a situation as this should exist only in very rare cases, if at all. A greater solidarity of effort would doubtless further both the ends for which the department exists, namely, the creation of truth and the dissemination of truth.

The greatest example in history of a nation which set itself to work on the problems arising spontaneously out of its own interest is afforded by the city-state of Athens in the fifth century before Christ. Here, to begin with, the people built up a form of government which did not copy the laws of any neighbor. They thought things out for themselves from their own point of view and were most pleased perhaps when their speculations resulted in conclusions contrary to those previously reached. There was a marvelous openness to new truth. Strangers might come into the city at will, teaching whatever doctrine they would and carrying away with them the new truth gathered from the thinkers of the city. The Greek was calculating in preparation, daring in deed, and untrammeled by preconception when his logic led him to new or strange conclusions.

Through Pericles they said of themselves, "We are not angry with our neighbor if he does anything to please himself." On the other hand, it was expected that each would work out his own pleasure and contribute to the general good by whatever means pleased him best. He should be spontaneous and give an expression of himself in all things that he did. Under such circumstances in one century the city of Athens "gave birth to more great men of the first rank than the whole world has ever produced in any equal period of time."

Great achievement is intimately bound up with spontaneity of interest and effort. Science truly is international and profits much by the interaction of one people with another, even to the extent of obtaining fundamental values in this way. But the primary need is that each nation shall set about its part of the common problem in a way of its own, allowing its national individuality full freedom for self-expression according to its peculiar bias. Otherwise its attainments are a mere appendage to those of another people and contribute but little to the general good which would not have been as well developed if that nation had never existed. And so it has come about justly that history has recorded permanently but little concerning any civilization which did not develop from within. Likewise no national contributions to science can be of great and abiding interest unless they spring up essentially from the life and thought of the nation itself.

In order that we may have the greatest development with the most important consequences we must have abiding with us in research the spontaneity of the nation, the institution and the individual; and the greatest of these is the spontaneity of the individual.

THE ROMANCE AND THE TRAGEDY OF SNEEZING

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SAN FRANCISCO

FROM time immemorial the sneeze has been deemed worthy of notice and has elicited some form of salutation from bystanders or some expression from the agent. The phrase, "not to be sneezed at," has behind it an importance attaching to the act of sneezing to which the whole human race bears witness. Even children notice it as something peculiar and have sayings of their own, such as, "Scat!" or "Shoo!" The origin of the importance attaching to sneezing is thus a question of psychological import as well as one of cultural diffusion.

As W. R. Halliday has remarked,

> It is *per se* a startling phenomenon to find the body, which in normal action is the instrument of the owner's will and intention, behaving in a way independent of his desire or volition. Simply because it is involuntary, the twitching of the eyelid or the tingling of the ear must be miraculous. And primitive man finds a significance in everything which attracts his notice, particularly in cases where there is no obvious cause.

This is good psychology and an array of facts can be adduced to prove the point. Before returning to the interpretation of the beliefs attached to sneezing, it will be well to describe some of the customs associated with it. The first instances will be cited from the classical cultures and from our own civilization, after which we will review the evidence from savagery.

Ancient Greece.—The ancient Greek greeted a sneeze with the words, ζῆθι, Ζεῦ σῶθον, "Live, Zeus preserve thee!" Aristotle declared the sneeze an honorable acknowledgment of the seat of good sense and genius. Accordingly, when a bridegroom sneezed an observer remarked, "Some good spirit sneezed out on thee a blessing"; and Penelope remarked, "My son has sneezed a blessing on all my words." Sneezing was the indication of life first shown by the man primeval endowed by Prometheus with living spirit. The custom has been handed down by the Greek Adam to his descendants.

Rome.—Petronius, Apuleius and Pliny tells us of the Roman custom of saluting one who has sneezed, and Plutarch declares that to sneeze before a naval battle betokens victory. The be-

lief was current among the Romans that when the Dogstar arose, the wild beast, which the Egyptians called Oryx, stood facing it steadfastly, and then sneezed, "as if it were worshipping it."[1] The Roman salutation was "Salve!" equivalent to our "May you have health!"

Persia.—In the Zoroastrian religion, according to the precepts of the Zend-Avesta, prayer is advised after sneezing. It is necessary to recite some of the sacred texts, for there is a fiend in the body. In the body is a fire, a disposition, or an instinct of sneezing; this wages war with the fiend; sneezing indicates the triumph of this disposition and the expulsion of the demon. One who hears the sneeze utters the same prayer as the sneezer.

Hindu.—The Hindu theory is that a spirit is entering or is leaving the nose. The bystander says "Live!" to which the reply must be made, "With you," that is, "The same to you," or the bystander says, "God bless you!" or, "God be praised!" —the last mentioned is borrowed from the Mohammedans. If one is beginning work and hears another sneeze, it is necessary to begin the task again. If one sneezes while praying he must begin again, otherwise his prayers will be offensive to the deity. Compare with this the English saying:

> To sneeze at prayer
> Is the devil's snare.

China.—In China when one sneezes he remarks: "I wonder who is talking about me!" A bystander may say, "Dai gut lai see!" "Good luck!"

Mohammedanism.—Replying to a sneeze is one of the duties recognized by the Mohammedans as among the Tarz Kafa'i, the sacred duties imposed upon the faithful. According to Abu Hurairah, Mohammed said: Verily God loves sneezing and hates yawning. If a person sneezes and says immediately thereafter, "God be praised!" one of the auditors must reply, "God have mercy on you." To this the sneezer replies, "God guide us and guide you." The nose is a dangerous retreat for evil spirits and the Mohammedan, when he rises in the morning, washes out the nose with water, for the devil has probably visited it during the night.

Jews.—A Jewish tradition states that before the time of Jacob men sneezed but once and then died—a curious swan's song. In order to preserve a memory of the happy substitution when men died from natural diseases rather than from a sneeze,

[1] Pliny, Bk. II., 40; Ælian VII., 8.

every prince commanded his subjects to employ a salutatory exclamation after the act of sneezing. The custom of replying to a sneeze existed among the Jews, whose formula was, "Tobim khayim," *i. e.*, "God (give you) life," or "Asusa," "Health." The sneezer generally recited Genesis XLIX., 18, "I have waited for thy salvation, O Lord"; and, when the bystanders blessed him, replied: "Be thou blessed." That the Hebrews probably regarded the sneeze as an indication of the coming or the leaving of the spirit is shown by 2 Kings IV., 35: When Elisha restored the Shumanite's son his return to life was signified by the lad's sneezing seven times, and then opening his eyes.

Christianity.—In early Christian times the sign of the cross was made by the sneezer, though later ecclesiastical advice was to pay no heed to sneezings. They were sometimes regarded as a momentary palsy. In vain, however, did Eligius (588–659), Bishop of Noyon, an eminent French clerical writer, admonish the Christians to "pay no attention to auguries and sneezings." Respect for them persisted, and a later tradition within the church found countenance for it by assigning its origin to an ordinance of Pope Gregory, who is said to have instituted a short benediction for such occasions. He was moved to this by the fact that a certain pestilence was attended by sneezing and these sneezes usually resulted in death.

However this may be, we find many survivals among Christian peoples of the superstitious respect attaching to this remarkable function. The Roman salutation of *Sit salutiferum* is preserved by Italians of to-day as Felicita, by the French as Bonne santé, or a "God bless you," by Germans as "Prosit!" or as "Gesundheit!" A German who sneezes while putting on his shoes accepts this as a sign of ill-luck; if he sneezes while telling something to another this is a sign of the truth of his assertion. In Esthonia if two pregnant women sneeze at the same time this is a sign that they will give birth to daughters; if their husbands sneeze in chorus this signifies that the children will be sons.

In the north of England, when one sneezes the formula is "Bless the bairn"; and children are still told:

> If you sneeze on a Monday, you sneeze for danger;
> Sneeze on a Tuesday, kiss a stranger;
> Sneeze on a Wednesday, sneeze for a letter;
> Sneeze on a Thursday, something better;
> Sneeze on a Friday, sneeze for sorrow;
> Sneeze on a Saturday, see your sweetheart to-morrow.

What the Sunday sneeze betokens we can only guess.

We probably have European influence in the belief of the negroes of Jamaica that if the nostrils itch so that you sneeze, some one is backbiting you; and also in the belief of negroes or North Carolina to the effect that if you sneeze while eating, you will hear of a death.

In Malta one says to the sneezer, "Evviva" or "Sahha!"

In England a sneeze is often greeted with, "God bless the Duke of Argyl," though this formula is an insult to a Scotchman.

Another English saying, "We are never so near death as when we sneeze," seems to indicate the idea that a sneeze is a sign that the soul is leaving the body.

In Ireland the bystander says to the sneezer, "The blessing of God and Holy Mary be on you!" or, "The consecration be upon you!" meaning, the holy water.

The Bohemian declares that should you hear a sneeze, and be unable to see the sneezer, you must say, "God make you well again." Perhaps it was a wandering soul which, by your kind formula, you have now delivered.

The "Rules of Civility" (translated from the French in 1685) declares: "If his lordship chances to sneeze, you are not to bawl out, 'God bless you, sir,' but, pulling off your hat, *bow to him handsomely* and make that observation to yourself."

In Bengal bystanders must make a profound bow in order to avoid ill-luck, and in Portugal it is still the custom for bystanders to remove the hat. Trajan, otherwise indisposed to attend to the ordinary civilities, was very punctilious in giving the proper salutation to sneezers, and expected a like return when he sneezed. It is said of the present German Kaiser that, having sneezed, and those present not knowing what to do, he remarked to those present, "I sneezed and no one said 'Gesundheit!'"

The Lower Cultures.—Having indicated the prevalence in the higher cultures of the superstitions attaching to the sneeze, we may turn our attention to similar beliefs among the lower peoples, where human nature is quite as much in the ascendant.

In Indonesia sneezing is taken as an indication that the soul is either leaving or returning to the body. The belief is widely prevalent that a sick man who sneezes will recover, since this happy event betokens the return of the soul. Among Torajas, Javanese, Battak and Dayaks, when a child sneezes its mother pronounces a wish that no spirit may take away the soul of the child. In the case of adults sneezing is a sign that friends think of them, or that enemies are attempting to injure their souls.

When the latter is the supposition, to prevent the success of these malicious designs, an imprecation is uttered by the sneezer.

If an Annamese child less than a year old is so inconsiderate as to sneeze, those present, apprehending danger, call out "*com ca*," "rice and fish," the cry which they raise when he appears to faint or when he starts nervously in his sleep.

The Melanesians, of the Solomon Islands, in Florida, and the New Hebrides, are similarly apprehensive of a child's sneeze. The Mafulu, of New Guinea, are said to have no superstition with regard to sneezing, but the Koita regard is as a sign that the soul has come back to the body. If a person does not sneeze for many weeks this is an indication that the soul is far away. In Miriam, one of the islands of the Torres Straits, when a man sneezes he accepts this as a sign that some one has mentioned his name. He immediately cracks the joints of each thumb by pressing the closed fingers of his respective hands upon the thumbs. In another of these islands, Kauralaig, it was the custom for the sneezer to make violent gestures with his hands and arms, presumably with the intention of driving away the evil influence that was seeking to take up its abode in his irritated nostrils.

Sneezing used to be in North Queensland, Australia, a far more potent thing than it is at the present day. According to a tradition current in the region of Charlotte Bay, one of the earlier heroes once gave a sneeze of such force as to dislodge from the crevice of a tree the arm of another who had not been able to disengage it. The romance of the sneeze has not entirely disappeared from that region, however, for at the present day, the natives declare, the sneeze of a man indicates that a woman is in love with him.

In Motlan when a child sneezes the mother says, "Let him come back into the world!" or, "Let him remain!" On Leper's Island when a child sneezes the people say, "Good wishes!" The soul has been away and has just returned. In Mota, under such circumstances, the saying is, "Live! Roll back to us!" The soul is being drawn out of the body through the nostrils into that other world beyond human ken. When an adult sneezes he says, "Stamp down the mischief from me! Let it be quiet!" or, "Let them say their words in vain! Let them lay their plots in vain!" Thus will the magic of his formula counteract the charm of the enemy.

In Siam those present wish the sneezer long life.

In Saa, one of the Polynesian islands, the sneezer says, "Who is calling me? If for well, good; if for evil, may I be defended!"

In Old Calabar people say, when children sneeze, "Far from you!" accompanying the words with a gesture designed to ward off the impending evil. On the other hand, the Toradjas, of the central Celebes, declare sneezing a sign that a sick person's soul has returned, and that he is recovering. In the Tonga Islands, to sneeze at the moment of setting out on an expedition is a bad omen.

> At this time Mr. Mariner, on entering the house, happened to sneeze! Immediately every one present threw down his club, for who would proceed on so important an expedition after so dire an omen! Finow's eyes flashed with the fire of rage; directing them full on Mr. Mariner, he cursed him with the most bitter curse, "Strike your god!"—and, rising from the ground, he demanded why he came there?[2]

If a Maori warrior sneezed when eating it was a sign that he would fall in battle and would be cooked and eaten by the enemy. The sneeze of a common person while eating, or when about to eat, signified that visitors or news would soon arrive; a charm should be said to avert the evil attendant upon a sneeze. To avert evil the Maori pronounced this spell when one sneezed:

> Sneeze, living Soul!
> In the light of day.
> Those on the sea are blest with plenty,
> There is plenty for the mighty lord.
> Sneeze thou!
> Baptized into life!

It was not necessary to repeat the whole charm, frequently only the first few words being recited. This charm, or another, was pronounced by the mother, to avert evil consequences, when her child sneezed. In giving a name to a child the "priest" chanted the genealogies of the male line; if the child sneezed, the name that was being uttered at this time was bestowed upon it—possibly because the ancestral spirit was supposed to be inspiring the sneeze. When the king of Sennaar sneezes his courtiers immediately turn their backs and slap their thigh, vigorously.

In the Congo, when the Mushidi, or chief, sneezes, all who hear it clap their hands loudly and shout, "Long live the King! Hail!" The oftener he sneezes the longer will be his life, a sneeze being but an outflow, or the overflow of a superabundance of life. Consequently, a paroxysm of sneezing evokes a chorus of approval. When a Bakongo sneezes some one sitting close by says, "Come quickly." If the sneezer be a child of tender years the mother calls out, "Come back quickly." This is to summon back the spirit which is supposed to be leaving the body when one sneezes. If any of the slaves buried alive at the

[2] J. Martin, "The Tonga Islands," p. 271.

death of a Yao chief should sneeze after being placed in the grave, he was spared, in the belief that the spirit had thus signified his refusal of that particular victim. Evndently, they were not in the habit of taking snuff—this would have been a life-saver.

A Gold Coast story speaks of a leaf, which, when a person smelled it, caused sneezing. "They rubbed the leaf upon the noses of the two cows. Then the cows at once looked as if they wanted to sneeze, and they rubbed the leaf on the noses of the two cows." A medicine-man attempted to restore a woman killed by witchcraft by inducing sneezing, presumably so that the evil spirit would escape—or her own return. When the king of Dahomey sneezed, all present touched the ground with their foreheads; but to sneeze in the presence of royalty was punished by a fine. Among the Ewe-speaking peoples to sneeze is a bad omen. Among the western tribes

> this involuntary convulsion is an indication that something is happening to the indwelling spirit, usually that it is about to quit the body; and as that affords opportunity for a homeless indwelling spirit to enter the body and cause sickness, the omen is bad. Among the eastern tribes, though the notion of the indwelling spirit has been to some extent confused with that of the ghost-man, the old superstition still prevails.

If the indwelling spirit should leave a man when he is awake, he becomes appraised of its departure by a sneeze or a yawn. Hence the sneeze is believed to indicate that the *kra*, one of the man's souls, is leaving the body, and the bystanders always offer some wishes of good health.

> Among the Tshi-speaking tribes a sneeze seems to be regarded as an evidence of something unpleasant or painful having happened to the indwelling *kra*. Hence, as the well-being of the man is indissolubly bound up with that of his *kra*, it is usual for persons to address wishes of long life and good health to anyone who sneezed, with the idea of thereby averting an independent ill.

When the king of Ashantee sneezes, every person present touches or lays the two first fingers across the forehead and breast, as the Moors did when they pronounced a blessing, and the Ashantees, invariably, to propitiate one. When the king of Monomotapa sneezed, it became a national concern. Those nearest the royal person howled a salutation, which was taken up by the antechamber; and when the horrid cry had run through the palace, it was re-echoed by the whole city.

When a Thonga sneezes, he is addressed with this good wish: "Life and sleep!" He himself calls upon the gods, saying:

> I pray to you! I have no anger against you! Be with me and let

me sneeze! Let me sleep and let me see life! so that I may go by the road, I may find an antelope (dead in the bush), I may take it on my shoulders; or that I may go and kill an elephant (meaning, meet with a girl and obtain her favor). Now I say it is enough, you nose!

The sneeze of a child during one of the ceremonies is ominous.

Any man who sneezed in the presence of the Zulu chief, Chaka, was instantly killed. The Xosa says, "Qamata help me!" Qamata being either a powerful chief or some supernatural being. Other Kafirs, when they sneeze, say, "Chiefs," or, "May the chiefs bless me!"—much as people in the lower classes in England say, "Lor' bless you!" To sneeze is thought to be a very good sign. In ancient days, when a Zulu chief sneezed, all the people near would say, "May the chief live long!" or, "May he grow greater!" If a sick person begins to sneeze, the people say it is a sure sign that he is about to recover, for the spirits are pleased." If he is ill and does not sneeze the disease is a malignant one. To a child who sneezes they say, "Grow!" for this is a sign of health. In the case of an adult it is a sign that the ancestral spirits have come to the agent and he returns thanks. This is especially true of the medicine-men. The Christian Zulus say, "Preserve, look upon me!" or, "Heaven and Earth!" Elsewhere, among the Kafirs,

Sneezing is considered a very good sign, and when a small child sneezes the mother says, "Thanks, Chiefs!" thus giving thanks to the ancestral spirits who are supposed to be shown by this sign to be taking care of the child. Sometimes when a child sneezes the mother will simply say, "Chiefs!" thus giving thanks to the *amatongo* (ancestral spirits). At other times the mother says, "Throw out and you will grow well."

The North American Indians, to mention but one more culture area, have attached considerable importance to the sneeze. Among the Eskimo of Hudson Bay, when a person sneezes, he must say to his soul, "Come back!" otherwise he might become sick. If a child sneezes, the mother smacks her lips, the appropriate response of the child which she performs for it. The sneeze of a sick person, however, is a sign of approaching recovery. The Bilqula declare sneezing an indication that people are talking about one. To sneeze three times in succession was believed by the Stlatlumh to bring good luck to the person sneezing. To sneeze through the right nostril is a sign of good fortune; to sneeze through the left, a sign of bad fortune.

The Wasco associate sneezing with mention of a person's name:

The young men asked, "Who is the chief of the village?" The old woman said, "We must not tell you. If we mention his name, that moment

he will sneeze and say, 'My name is mentioned in the old house at the end of the village,' and he will send to see who is here," but the brothers insisted. At last the old woman told him, and that instant the chief sneezed and sent to the house.

The same belief is found among the Takelma, where a person who sneezes says, "Who calls my name?"

"Thou shalt prosper," shall he say of me, "yet another day shalt thou go ahead." (That is, "mayest thou continue to live.") Ye shall blow to me,

meaning, "blow a whiff of tobacco smoke for my prosperity." Here, too,

When a person sneezed, it was believed that his name was being mentioned by some one afar off. To prevent the evil effect to the person named of a possible mention of his name in connection with ill wishes (for words as such may have power of good or ill), it was customary to apostrophize the absent ones: "Who is it that calls my name? May ye (who speak to me) say in regard to me: 'Do thou prosper, mayest thou go ahead [*i. e.*, continue life] yet another day!' May ye blow to me!"

Among the Yana a woman says:

May I be happy! Do you people not speak about me! Do you speak for my happiness when speaking about me!

A man says:

May I be happy! May my legs feel light! May you people speak for my happiness! Would that you would let me alone! I bathe, and I go back into my house, and I rejoice in my eating.

Among the Dakota to sneeze once means that a man's special friend, his son, or his wife, has pronounced his name; whereupon he calls out, "My son." If he sneezes twice he exclaims, "My son and his mother." When a Crow Indian sneezes bystanders say to him, "They are calling you; that is why you sneeze," though the remark is said to be regarded simply as a joke. The Apache remarks, "Some one calls my name." The Pima pronounces the names of Earth Magician and of Elder Brother, two of the culture heroes, when he sneezes; or, he may simply exclaim, "Pity me!" as a plea to one of these two creatures. The Guiana Indians believe that during sneezing or yawning the soul is temporarily leaving the body, though what they do about it we are not told.

When De Sota, in the year 1542, was interviewing the Cacique Guachoya, the latter happened to sneeze. Thereupon all the attendants of the cacique bowed their heads, opened and closed their arms, and made signs of veneration, saluting their prince with such phrases as, "May the sun guard you!" "May the sun shine upon you!" "May the sun defend you!" "May the sun protect you!"

The Ominous Sneeze.—As we have seen, the sneeze is frequently accepted as indicative of good or of ill luck, and sometimes there is a further specification of the fortune, good or bad, to be expected.

In the island of Florida the sneeze indicates that some one is speaking about the man, is angry with him, is calling upon his *tindalo*, or personal ghost, to eat him. He accordingly responds by calling upon his own *tindalo* to take revenge on the man who would injure him. In the Celebes a man who sneezes when about to part company with friends must return, and sit down awhile in order to fend off the impending ill.

The Siamese consider it lucky to sneeze many times. They believe also that the judges of the lower realm of shades keep a book in which the name of every one is registered, and that, when this book is opened all those whose names appear on the page that is observed sneeze. Their optimism, therefore, seems to indicate great faith in a clear record on this golden book. To the Chinaman, too, the sneeze indicates luck, and the gambler who sneezes knows that he will win. In many parts of Europe to sneeze when one sees a hearse indicates that another death will soon occur in that vicinity. In India to sneeze at the threshold is unlucky. The Romans declared that when a cupid-like little boy sneezed the birth of a beautiful girl baby was thereby indicated.

The Greeks considered sneezing to the left unlucky, but lucky if to the right. When Themistocles sacrificed in his galley before the battle of Xeres, and one of the assistants upon the right hand sneezed, Euphantides, the soothsayer, presaged the victory of the Greeks and the overthrow of the Persians. When Xenophon was addressing his troops, the doughty ten thousand, and his remarks, "We have many reasons to hope for preservation," were punctuated by a sneeze from one of the attending soldiers, Xenophon paused, then resumed: "Since, my fellow-soldiers, at the mention of your preservation, Jupiter has sent this omen." Xenophon had previously profited by this omen, for he owed his appointment as general to the happy event of a sneeze to the right of him while he was making a speech. On each occasion the army accepted the omen and the men were inspired with new vigor. The custom of regarding the sneeze as ominous is as old as Homer. Evidence of this is to be found in the eighteenth book of the Odyssey:

> **She spoke: Telemachus there sneezed aloud;**
> **Constrain'd, his nostril echo's through the crowd.**
> **The smiling queen the happy omen blest:**
> **So may the impious fall, by fate opprest.**

Aristotle puzzled over the problem—And is it not enough to try the mettle of any philosopher?—"Why sneezing from noon to midnight was good, but from night to noon unlucky." St. Austin declares: "The ancients were wont to go to bed again if they sneezed while they put on their shoe."

In England, as still in Siam, much sneezing is regarded as favorable. "Two or three neses be holsom; one is a shrewd token," says an old English motto. "He hath sneezed thrice, turn him out of the hospital," was a seventeenth-century proverb, an assurance that the patient will now do well. Sir Thomas Browne recognized it as in the main a good sign and approved of the giving to persons near death a medicine which would induce sneezing—"if the faculty arise, and sternutation ensues, they conceive hopes of life, and with gratulation receive the sign of safety." If a sick person can not sneeze the disease will end in death—a belief which we have found in other parts of the world. Sir Thomas Browne assures us, however, that sneezing is bad if the patient be an unmarried girl, a widow, a barren wife, a shoe-maker's wife, a woman sick with the cholera.

The meaning attached to sneezing by European peoples is of various kinds. An unsuccessful attempt to sneeze indicates that you will lose something of value; but if you sneeze violently enough to tear a buttonhole out of a shirt, dress, or vest, riches are rapidly coming your way. It is good to sneeze while reading, when launching an argument, when about to retire, when eating—though, as to the latter, negroes declare it betokens news of a death. It is good to sneeze at seed sowing, for the harvest will be great. You will not sleep well if the servant sneezed while making up your bed—possibly because you will be amid too much dust. Two men talking business and sneezing simultaneously have cause for mutual and self-congratulation. The soldier who sneezes at the mention of an approaching battle will be on the side favored by victory. (Then may such a sneeze go forth from all the Sammies and Tommies as will blow the enemy ——! But, doubtless, they are sneezing enough.) To sneeze twice each night for three successive nights is a sign of approaching death. If you sneeze between eleven and twelve o'clock, you may expect a stranger. Husband, beware: If you sneeze while you are getting up in the morning, lie down again for another three hours, else your wife will be master for a week. Whether any worse fate awaits the husband who adopts the above-mentioned prophylactic, who can say?

To sneeze before breakfast is well; you will receive a present that day, unless it be Sunday; in which case declare Vermonters, you will hear of the death of a friend before another Saturday night. Instead of waiting until the preprandial hours of a Sunday morning, sneeze rather on Saturday night after the lights are out, and, on the following day you will be rewarded by the sight of a person whom you have never seen before—a promise perhaps more inspiring to the countryman than to the dweller in the city. If you sneeze with food in your mouth you will hear of the death of a friend; every time you sneeze at table there will be one more or less the following meal. Whether it be more or less may depend, we surmise, on whether the old Roman advice was followed—*Sternutare volens vicino obvertito vultum*—when you sneeze turn aside your countenance from your neighbor—; or whether, on the other hand, the advice was followed which is given in a book called "The Schools of Slovenrie, or Cato turn'd wrong side outward, translated out of Latin into English Verse, to the use of all English Christendome except Court and Cittie; by R. F. Gent., London, 1605," wherein we read:

> When you would sneeze, strit turn yourselfe into your neighbor's face:
> As for my part, wherein to sneeze, I know no fitter place;
> It is an order, when you sneeze *good men will pray for you;*
> Mark him that doth so, for I thinke he is your friend most true.
> And that your friend may know who sneezes, and may for you pray,
> Be sure you not forget to sneeze full in his face alway.
> But when thou hear'st another sneeze, although he be thy father,
> Say not *God blest him*, but *Choke him*, or some such matter, rather.
> . . . . . .

Aristotle's explanation of the respect shown to sneezing is that the first men, viewing the head as the principal seat of the soul, an intelligent organ governing as well as animating the entire body, carried this respect to sternutation as the most manifest sign of life. Hence the compliments heaped upon the sneezer. Since it is a motion of the brain suddenly expelling through the nostrils what is offensive to it, it can not fail to afford some evidence of the brain's, that is, the mind's vigor. Aristotle's view is endorsed by Sir Thomas Browne.

That some peoples should attach a sinister meaning and others a favorable meaning to the sneeze is not difficult to understand. Fear of bad consequences leads to the pronouncement of a formula, a blessing designed to ward off the evil. The pronouncement of a blessing or of wishes for one's welfare may easily pass over into expectation of its fulfilment, and, conse-

quently, of benefits. Eventually the benefits are thought of to the exclusion of the threatening evils, and hence the sneeze becomes propitious. It is easy to see that a people may entertain one or the other attitude toward it; and that, possibly as the result of accidental association, particularly should it receive confirmation, some sorts of sneezes may be considered propitious and others dangerous.

Thus the explantion of the curious beliefs associated with the extraordinary phenomenon of sneezing is not far to seek, and has already been repeatedly given in the various practices already described. The soul often finds exit or entrance by the nose or by the mouth, for it is in large part identified with the breath. The breath of the nostrils is indeed the life of a man, and his life force is intimately bound up with his soul. For this reason the nostrils as well as the mouth of the dying man are sometimes held or closed to keep in the soul. This is done sometimes for the benefit of the deceased, since this soul should accompany the body wherein it has resided, and sometimes for the benefit of the survivors who have little desire to remain in the company of the disembodied spirit of him with whom they associated in life. In the Celebes fish hooks were attached to a man's nostrils to impale the soul of the dying should it attempt to escape. Eskimo mourners, or those who prepare the body for burial, plug the nostrils lest the soul which is supposed to remain with the body should find exit and follow the migratory soul of the dead to the land whence souls are reincarnated. It is not uncommon for savages, while sleeping, to cover the nostrils and the mouth, to prevent the escape of the soul unknown to the unconscious owner. Even the cultured Greeks and Romans were not averse to leaning over the dying man in order to obtain the spirit of the departed by inhaling his last breath, and so receiving his spirit into themselves.

This, coupled with appreciation of its startling and peculiar nature, is the philosophy which has given rise both to the romance and to the tragedy of the sneeze.

PHYSIOLOGICAL INERTIA AND PHYSIOLOGICAL MOMENTUM

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NEWTON'S first law of motion states: "Every body continues in its state of rest or of uniform motion in a straight line, except in so far as it is compelled by forces to change that state."

The conception of inertia is inherent in this famous definition, for that property of matter in virtue of which matter tends to maintain its state of rest or of uniform motion in a straight line, is called inertia.

Functional inertia is that property of living matter (bioplasm) in virtue of which, having received a stimulus, it continues to maintain the functional status quo ante, whether that was activity or inactivity; and functional momentum is that property of bioplasm in virtue of which the living matter, having responded to a stimulus, continues to exhibit its activity or inactivity after the stimulus has ceased to exist. Functional or physiological inertia is that property of living matter which maintains the status quo ante, namely, non-response to a stimulus tending to arouse a response (functional inertia of rest), or response after the stimulus has ceased (functional momentum).

Affectability is that property of living matter in virtue of which it responds to a stimulus either by activity or by the quelling of activity (inhibition). States of inactivity or inhibitions are, therefore, equally with activity responses to stimulation. We may express the inter-relations of these factors as follows:

A stimulus having been received, then if affectability predominates there may be either activity or inactivity; and conversely, if functional inertia is predominant when the stimulus is received, there will be activity, if activity was the status quo, but inactivity, if inactivity was the status quo. Finally, the stimulus having ceased to act, there will be, owing to functional momentum, activity, if activity was the status quo, inacivity if inactivity was the status quo. As a recent writer

in *Nature* puts it—"Responses to stimuli cannot take place instantly, neither do stimulation effects fade away momentarily."[1]

Some definite examples might be given: a stimulus is applied to a muscle at rest; the muscle does not shorten until after a "latent period" which is lengthened by cold and fatigue: here the functional inertia of the muscle maintains the status quo ante of inaction: the heart is beating when a stimulus tending to stop it (inhibit) is received, the heart makes a beat or two before it stops; here the status quo ante of activity was maintained.

If the cardio-accelerator nerves of the heart are stimulated, the heart's action is accelerated, on stopping the stimulus the heart continues to beat fast for some time before it resumes its pre-stimulant rate; this is post-stimulant activity due to physiological momentum. If the vagus or inhibitory nerve of the heart is stimulated, the heart can be brought to a standstill; when the stimulus is withdrawn, the heart remains quiescent for some time before it resumes beating; this post-stimulant inhibition is due to functional momentum.

Both properties, affectability and functional inertia, coexist in bioplasm, at one time one predominates, at another another. Thus, in the heart cycle during systole, functional inertia predominates, for a stimulus given during systole is totally disregarded (refractory period). During diastole, affectability predominates, and a stimulus given during that phase elicits a small systole (extra systole). This functional inertia during systole makes it impossible to tetanize the heart.

These limits set to metabolic possibilities are due to the possession of functional inertia, a property possessed contemporaneously with affectability. Thus, as I wrote in 1908, the manifestation of life at any given instant is to be regarded as the resultant of two coexisting but physiologically opposite functional propensities or capabilities; the degree of whose relative intensities conditions the character of the particular manifestation at the moment; response if affectability be the predominating condition; non-response if functional inertia be the characteristic state. Non-correspondence with environment is the keynote of protoplasmic inertia; independence of environment, disregard of stimulation, inaccessibility to external influences, insusceptibilities, resistances, limits to powers of response—a holding on the even tenor of the metabolic way.

Limits to rates of activity, superior limits to rhythms, are inertial. Cilia bend to and fro at about ten to twelve a second

[1] *Nature*, January 3, 1919, p. 354.

at ordinary temperatures; but on being heated can not do so faster than twenty a second. Thus the (rabbit's) heart heated can not perform systoles at a greater rate than six a second, our respiratory center can not discharge impulses at a greater rate than about two per second, we can not perform twitching movements of the fingers at a greater rate than about twelve a second, nor articulate more than about ten to twelve syllables per second, and so forth. Professor Sir A. Schäfer, Professor Waller, Professor Starling, Sir S. Sharkey and the late Professor Mosso, all use the term "inertia" as referring to nerve cells.

Closely allied to inertial limits are inherent rhythms, as demonstrating a disregard of environmental stimuli. For instance, the "post-tetanic tremor" (D. F. H.) in which a muscle twitches at about four to six a second, although it is receiving stimuli at a rate which, when it was unfatigued, produced in it complete tetanus.

Protoplasmic inertia is the physiological counterpart of affectability. Dead organisms have no affectability at all, but infinitely great functional inertia. Those in latent life (Scheintod) have very little affectability and much functional inertia. Thus the dried Rotifera, Tardigrada and many ova amongst animals; and seeds, resting (winter) buds and frozen bacteria, etc., amongst plants, are all cases of insusceptibility due to the possession of a high degree of functional inertia. Seeds, for instance, have little affectability; they will give an electric response to a powerful condenser discharge sent through them, but otherwise their inertia is extreme. As a French writer puts it, they are "tombés dans un état d'inertie complète." Writers in clinical medicine clearly recognize the condition which I am describing as a fundamental property of protoplasm. Thus Dr. R. W. Leftwich[2] writes of a type of coughing that "persists for long after the condition which produced it has passed off."

My early critics misapprehended my position in one or two respects; some complained, for instance, that functional inertia explained "too much." They might as well have complained that affectability explains too much. They failed to recognize that both these fundamental, vital properties—affectability and functional inertia—are coexistent and omnipresent, that there is no portion of living matter that does not possess

[2] "Aids to Rational Therapeutics," R. W. Leftwich, M.D., London, Bailliere, Tyndale, Cox, 1918, p. 6.

some of each property, and that, therefore, between them they must "explain" the whole of life. Of course no property of protoplasm "explains" life; but all manifestations of livingness are dependent on the simultaneous possession by living matter of two complementary and equally fundamental properties, affectability and functional inertia. At no time in the life of the organism is there absolutely only one of these properties in existence; in death functional inertia is maximal and affectability has disappeared. The converse of this, a state of infinite affectability with no functional inertia, is not known now and here on this globe.

Physiological insusceptibility may be absolute, as in such cases as light waves falling on the auditory nerve or sound waves on the optic where there are no responses whatever. These and similar conditions might be called absolute functional inertia; but inasmuch as the stimuli are not only heterologous but perfectly inappropriate, these cases need not further detain us. The case, however, of the stigma of a particular species of plant being insusceptible of fertilization by the pollen of some other species is another case of the same sort of inertia.

Certain idiosyncrasies may be related to the two properties of protoplasm thus—extreme "susceptibility" towards a poison or drug is due to extreme affectability towards it, whereas a high degree of resistance to a poison or drug is the outcome of a relative functional inertia towards it.

A tissue performing some chemical transformation may exhibit functional inertia under one of its many aspects; the tissue or organ may exhibit a longer or shorter latent period after the exciting stimulus has been received; it may maintain its own particular rate or pace of activity; it may produce its own proper chemical transformations after the stimulus has ceased to exist; and, finally, it may be concerned in such an activity as the excretion of uric acid, which is in itself regarded by some physiologists as chemically a vestigial process. On this view, the excretion of uric acid by the mammal is a survival of a chemical activity characteristic of an avian ancestor. The excretion of this acid is thus an example of the maintenance of a chemical status quo ante.

Physiological momentum is strikingly shown by certain vegetable organisms. The opening and closing of certain flowers goes on for some days after the plants have been placed in the dark; "the seasonal periodicity is exhibited by deciduous

trees when removed to countries where the vegetation is evergreen."[3]

Professor W. A. Osborne, of Melbourne, Australia, found that his diurnal curve of temperature maintained its subtropical character for some weeks after he had been living in the temperate zone.

The time of onset of menstruation affords another example; the Hindoo girl begins to menstruate at twelve or thirteen, the English at fourteen to seventeen years of age; an English child taken to India begins this function not at the age appropriate to the native race and the hot climate, but at that indicative of her own.

Birds in captivity, removed from all circumstances that might be supposed to indicate or necessitate journeys, nevertheless become restless at the return of the season for migration.

All activity of organs after the death of the body as a whole (somatic death) are examples of physiological momentum; thus, the possibility of the perfused heart beating, of the liver secreting bile, of the skin glands and hairs surviving, of nerve fibers remaining active, and so on, are all examples of it.

The over production of anti-toxin after the stimulus (toxin) has ceased to operate has been repeatedly quoted by medical writers as a striking example of physiological momentum.

The relations of functional inertia to heredity are intimate and obvious. If functional inertia is a property of cells, and therefore of tissues, organs, systems and organisms, it must also belong to the individuals who compose the race. It is responsible for racial characteristics, it moulds national destinies. Thus, races with much functional inertia, which learn anything new with the utmost difficulty, remain in their racial *status quo* century after century. "Oriental inertia" is, in fact, the term universally used to describe their state of non-receptivity, their holding on in the straight line of their ancestral path.

There is an inertia of character in the family, clan, nation or race. As I wrote in 1908,[3a]

> By environmental stimuli acting through affectability we become educated or trained to be what under other circumstances or in another environment we might never have become; whereas through functional inertia, character is inherited and certain tendencies become innate, and one's individuality unfolds as the underlying ground tone of the life, until we are what we could not in any way whatever help becoming.

[3] R. A. Robertson, "Functional Inertia in Vegetable Organisms," *P. R. S. E.*, 1901–02.

[3a] The functional inertia of living matter. London, Churchill. 1908.

By internal momentum, the "person," character, individuality, is forced into manifestation in opposition, it may be, to parental objections, the teacher's frown and the disapproval of society generally. It was not affectability in the Bourbons which caused them to be described as learning nothing and forgetting nothing. Functional inertia preserves race peculiarities and guarantees constancy of type through very long periods of time. As Huxley well said, "any admissible hypothesis of progressive modification must be compatible with persistence without progression through indefinite periods." He then proceeds to remark that no order of fishes is known to be extinct. Huxley accepts Haeckel's view that "living matter is urged by two impulses, a centripetal, which tends to preserve and transmit the specific form, and which he identifies with heredity, and a centrifugal which results from the tendency of external conditions to modify the organism and effect its adaptation to themselves. The internal impulse is conservative and tends to the preservation of specific or individual form."

Huxley has described these two tendencies in living matter so well that I must quote from him once more.

The tendency to reproduce the original stock has, as it were, its limits, and side by side with it there is a tendency to vary in certain directions, as if there were two opposing forces working upon the organic being, one tending to take it in a straight line, the other tending to make it diverge from that straight line, first to the one side and then to the other.

The former tendency I attribute to functional inertia, the latter, of course, to affectability.

Professor J. Arthur Thomson, of Aberdeen, is very emphatic when he writes,[9] "in the light of the fact that frequent as variations are, hereditary constancy or inertia or persistence of specificity is even more marked." He is constrained to use even the very term "inertia," and entirely in my sense, in his valuable and exhaustive monograph on "Inheritance."

Psychic Inertia and Psychic Momentum

Inertia and momentum are as clearly demonstrable in the things of the mind as they are in those of the body. Sensations, concepts, emotions, ideas—all mental states—would seem to possess functional inertia and momentum as distinctly as it is possessed by the underlying substance of the nervous system. (I shall not now digress to debate the subject of the causal interdependence of the activities of the nervous system and mental or conscious manifestations, although I may remark that I am a thoroughgoing interactionist.)

Dealing in the first instance with sensations, the argument somewhat as follows. If functional inertia and functional

[9] *Jour. Royal Micros. Soc.*, 1916, p. 448.

momentum are properties of cerebral protoplasm, they must also characterize sensations which have the activity of cerebral protoplasm as their causal physical basis. Professor J. McKeen Cattell long ago put it so well that his words may be quoted. "Inertia is a property of our sense-organs. The molecules of the cells are only set in motion after they have been worked upon by a stimulus of a certain strength for a certain time, and the motion continues after the stimulus ceases." Here Professor Cattell recognizes both psychic inertia and psychic momentum. The latter, indeed, had long ago been described by Hobbes (died 1679) in these words: "Like water troubled, an organ of sense will remain in motion after the removal of the exciting agent." Haller (who died in 1777) wrote, "these" (mutations of cerebral substance) "persist for a long time after the cause which gives rise to them has ceased to operate."

Psychic momentum underlies all those sensory phenomena known as positive after-sensations. The positive after-image is due to this psychic momentum, advantage of which is taken in the kinematograph in which a series of brightly illuminated instantaneous photographs of moving objects produce, by their retinal persistence, the illusion of continuous movements. If each impression vanished instantly, then there would be intermittency or flicker and no fusion of effects, as does occur when the photographs are run through too slowly, giving time for the after-images to fade away. But any given image "outlives" its stimulus in virtue of its functional momentum, and, fusing with the next oncoming image, produces the desired illusion of continuous action and not what it really is, a series of a large number of instantaneous views of moving objects.

On the material side, the positive after-image is due to the functional momentum of the retino-cerebral substance. To its existence is due the fact that a disc half white and half black, rotated in front of us, appears grey; or one half red and half blue, purple; and so on. The fusion of effects is only possible because of persistence of retinal impressions, and these are the results of physiological, psychic momentum.

Similarly, we *feel* contacts, pressures, pains, etc., long after the sources of these sensations have been removed. Who has not still felt his "rubbers" on his feet for some time after he has thrown them off?

Professor Sherrington is constrained to use the very word "inertia" in his article on "Skin, and Common Sensation"[5]

[5] "Text-Book of Physiology," edited by Schäfer, London and Edinburgh, 1900, Vol. II., pp. 998–999.

thus: "The inertia of the pain apparatus and the inertia of the organs for pain seem particularly great." Writing of pressure applied to the skin, the same author writes, "Pressure applied to the skin makes a sensation which does not subside—the sensation continues."[6] This is psychic functional momentum.

Four years after my views on functional inertia had first been put down on paper, I came across (1903) a notable lecture delivered in 1818 by Michael Faraday to a society in London known as the "City Philosophical Society." Speaking of inertia, Faraday says:

> Whatever is in motion is by it retained in motion, and whatever is at rest remains at rest under its sway. It opposes every new influence, strengthens every old one. Is there nothing in the human mind which seems analogous to this power? Is there no spiritual effect comparable to this corporeal one? What are habits? Old prejudices? They seem something like a retention in a certain state due to somewhat more than the active impulses of the moment. . . . The mind seems to remain in the state in which it is, and the words which enunciate parts of our natural law will describe exactly the effect . . . to illustrate at once the force of mental inertia.

Continuing, Faraday writes: "Apathy will represent the inertia of a passive mind, industry that of an active mind." The expression "inertia of the mind" frequently occurs. Enough has been quoted to show that Faraday had clearly before him the reality of mental inertia and mental momentum. The well-marked tendency to do what has been done before, to continue doing what you have just been doing, to yield to the familiar, to habit, is nothing else than the expression of psychic momentum. Every day we have examples of it; some one reads from the newspaper, "thirty or forty" when it was "thirty or fewer" that was written. Oliver Wendell Holmes alleges that not one in ten people can read Judges XV: 16 correctly; the verse is, "And Samson said; with the jawbone of an ass heaps upon heaps, with the jaw of an ass have I slain a thousand men." Nearly every one reads "jawbone" for "jaw" in the second clause.

Mental inertia and mental momentum must be as universal as mental affectability.

Bigotry, superstition and extreme dislike to change are expressions of psychic inertia, while obsession with an "idea" and fanaticism are those of psychic momentum. The riots which occurred in many parts of England on the introduction

[6] *Ibid.*, p. 925.

of machinery, and the violent protests that were raised against the making of railways in the early nineteenth century, are examples of the operation of national functional intertia.

It must not be supposed that the expressions of mental functional inertia are confined to the unreflecting proletariat; practically all the great discoveries in science and medicine have met with opposition not because they were not beneficial, but because they were new.

The discoverers of the circulation of the blood, of vaccination, of anesthetics, of the germ-origin of disease were obstructed and attacked not only by the laity, but by their own professional brethren. Galileo, Harvey, Jenner, Simpson, Pasteur and Lister were worried, ridiculed and persecuted, as all students of the history of discovery know.

Many writers have identified habit with inertia, thus Frank Buckland wrote of the "vis inertiæ of habit" in fish.

Of course it is in religious systems that we find the most perfect examples of psychic inertia and of psychic momentum. As Herbert Spencer put it, "Religious dynasties have extraordinary powers to resist change." National psychic inertia is expressed by national religion. The stolid, fatalistic and unprogressive Oriental is merely expressing his racial, mental inertia.

By psychic inertia instincts, capabilities and incapabilities, predispositions to all manner of activities and non-activities, are carried over into the next generation where they unfold themselves and maintain themselves, not only not in harmony with the environment but often in opposition to it. The environment in matters psychical is chiefly constituted by education and all that that means.

Educability is psychic affectability, ineducability is psychic inertia. It is this that Professor Ribot alludes to when he says that heredity has set a limit to the education of the negro. This is only another way of saying that it is the misfortune and not the fault of the negro, as it is with all who have inherited ineducable disabilities.

This pessimism has been extended by Monsieur Guyau when he says that education is powerless to modify to any great extent the radical temperament or character of the individual. According to this view, the criminal as well as the poet *nascitur non fit,* the child's whole moral destiny is contained within it while as yet unborn.

We may take the hypnotic trance as a good example of

psychic inertia, in that phase of it in which profound anesthesias and analgesias are developed so remarkably and so mysteriously.

The Origin or Genesis of Functional Inertia

All the properties or powers of living matter are not possessed exclusively by living matter. Certain properties or powers are characteristic of living matter and are not possessed by matter that is not living. Thus, the powers of reproduction, digestion and assimilation, are characteristic of living matter and are not shared by matter that has not ever lived. Crystals, for instance, do not reproduce themselves, nor can they incorporate material dissimilar from their own substance; but it is just these things that living beings can do. The "growth" of a crystal has nothing in common with the "growth" of an organism except the name.

Non-living matter is, however, affectable; if by affectability we mean the power of responding to a stimulus. Thus, gunpowder is highly affectable towards a spark, in that it will respond to such by an explosion, that is, it will convert violently its potential chemical energy into the kinetic forms of heat, light, sound and molecular disruption. Gunpowder, therefore, has affectability towards sparks as "stimuli." But gunpowder will not be exploded by concussion; it has, therefore, inertia towards concussion as a stimulus; if it is the "function" of gunpowder to explode, then it has "functional" inertia towards concussion, but high affectability towards sparks.

Affectability and functional inertia are possessed by such kinds of non-living matter as are designed to transform energy that is, to perform functions. Another example may be taken in the case of cordite; if it is the function of cordite to explode, then it has affectability towards concussion which causes it to explode, but it presents functional inertia towards sparks, which merely make it burn, but not explode.

It is, therefore, highly probable that just as the affectability of living matter is foreshadowed by that of non-living matter, so physiological inertia is foreshadowed by the inertia of non-living molecules.

As a pure speculation, protoplasmic inertia may be assumed to have been evolved from the molecular inertia of non-living matter and in particular from that of the carbon atom. Professor J. C. Bose, of Calcutta, has contrived to demonstrate in non-living matter such phenomena as latent period, post-stimu-

lant effects, and fatigue, on the one hand, as well as staircase responses, summation of effects, diphasic electrical variation, the results of varying temperatures and of different poisons, on the other. Such results are due to the existence of molecular inertia and of affectability respectively in the non-living mechanisms with which he worked.

Affectability and functional inertia are, therefore, not differentiae of living matter in the sense that the powers of reproduction, assimilation and excretion are. Only living matter can grow (metabolise) and reproduce itself, but both non-living matter and living matter can, under certain circumstances, respond to a stimulus, and under others, refuse or fail to do so.

Molar and molecular inertia are universal properties in that they are possessed by all forms of matter and by all mechanisms whether living or non-living which have the power of transforming energy.

Functional or physiological inertia is a property of all living matter (bioplasm) not merely by way of analogy with the inertia of non-living molecules, but because in its genesis such a property must have been derived from the fundamental property of non-living matter.

THE WHITE MAN'S MAGIC IN HOMER

By JONATHAN WRIGHT, M.D.

IN a previous essay which, as it was, occupied too much space in this journal (December, 1918), there was especially one aspect of the subject of *the foundations of belief of primitive men* to which I wished to give greater extension, but which I was obliged to pass over with a mere allusion. It was in sequence to the assertion that "all students of the dawn of history—all those who have pried into the practical life and the esoteric life of the ancient Oriental civilizations, so far as their details before the Trojan War have been revealed to us, feel that with the advent of the northern races around the Ægean Sea something almost cataclysmic happened in the smooth course of the progress of thought and emotional life, in philosophy and art and religion."

As to medicine, the remark has been made by others doubtless, but it impressed me much at first, that in the works of Hippocrates we find about as little of primitive magic as we do in the most recent professional works of modern medicine. It helps us to realize how high was that civilization from which Hippocrates drew his inspiration, the culture that had been evolved by Thales and Anaximander, by Heraclitus and Democritus in science and which was adorned, as no other civilization had been before or has been since, by Plato and Aristotle, by Æschylus and Euripides, by Pindar and Anacreon, by Phidias and by Praxiteles in philosophy and art. When the full realization of the glory of Greece is borne in upon us we no longer wonder at the remoteness of Hippocratic medicine from the charms and the incantations of Malay Magic and African ju-ju.

Elsewhere I trust I shall have an opportunity of tracing back from Hippocrates through Empedocles and Alcmæon some of the primitive traits recognizable in the fragments of the nature philosophers in connection with the earlier thought to be found in the Zend Avesta and the Rig Veda and even in Homer. To a certain extent these, especially the Zoroastrian and the Hindu Epics, are stepping stones back along the path to the Papyros Ebers and the Poem of Gilgamesh, but with these we need not here concern ourselves.

I wish here to dwell a little upon the assertion frequently made by many more recondite authors, but most popularly set forth in the attractive works of Leaf and Mahaffy and Murray and the many essays of other facile writers on Greek archeology, that there is little magic in Homer, scarcely anything in the Iliad at least. In the previous essay alluded to I have pointed out that we understand the ancient Greek because a part of his blood or at least his culture had come down to us from the western and northern slopes of the Alps before modern research studied it in the remains of ancient Greece. His methods of thought, his poetry and his dramatic art are familiar to us on this account, but we look down the paths of the black race, so intimately in touch with the civilization of the Mediterranean peoples before the first millennium B.C., and they are dark to us. Neither the black magic nor the white magic of the black man appeals to us at all as art in poetry or as logical in philosophy.

As we read the Homeric poems, possibly taking shape from the traditions of the people at a date ranging from the ninth or tenth to the seventh century before our era, we find very little indeed which we can assimilate with Oriental magic, the magic of the Malay or the African in his native jungles. We can find some explanation of its absence in the consideration that while the Iliad deals professedly with events which modern archeology places at least as early as the beginning of the first millennium B.C., they manifestly could only be expected to reveal those ideas and ideals, customs and manners and ways of thought familiar to the stage of culture in which they were written, extending well into a period of civilization in the Mediterranean basin, which was far removed, whatever its origin, from that of primitive man. Nevertheless, we have every reason to believe that at some period of the Hellenic culture there must have existed a state of art and thought which might fairly come within the definition of primitive. That this stage of social evolution antedated the first millennium B.C. might easily account for the absence of magic in Homer as it does in Hippocrates, but, so far as I have been able to remark, archeological investigation reveals plenty of primitive magic in Greece later than the date of the Trojan War.

There is, however, an argument which the attentive reader of the Iliad and the Odyssey may gain from the poems themselves. All critics bear out the statements, frequently made by philologists and antiquarians, that the Odyssey is of a later authorship than the Iliad, perhaps two or three hundred years

later. Now, it is precisely in the Odyssey that we are able to take notice of traces of magic to which modern ethnologists and archeologists have for many years constantly drawn attention. According to Abbott,[1] speaking of the Epic Cycle, the whole series of the Trojan poems, including the *Iliad* and *Odyssey*, is as follows:

1. The *Cypria*, of which the authorship is doubtful. Some considered it the work of Stasinus of Cyprus; others attributed it to Hegesias, or Hegesinus, of Salamis in Cyprus; others, again to Homer.
2. The *Iliad*.
3. The *Æthiopia*, by Arctinus of Miletus.
4. The *Little Iliad*, by Lesches of Mitylene.
5. The *Capture of Ilium*, by Arctinus of Miletus.
6. The *Nosti*, by Agias of Trœzen.
7. The *Odyssey*.
8. The *Telegonia*, by Eugammon of Cyrene.

In this series each poem takes up the story where the preceding poem ends. The same incidents are not repeated in any two of them, with some slight exceptions. . . . From the nature and construction of the Cyclic poems we were inclined to draw the inference that they were composed after the *Iliad* and *Odyssey*, and our conclusion is confirmed by what we know of the incidents recorded in them.

The great German critic Wolff made the assertion it has been difficult to refute that no texts of Homer or the Epic Cycle with which we are familiar existed before Alexandrian times.

Miss Harrison[2] perhaps makes use of her own notes when

The ghosts in the Nekuia of the *Odyssey* "drink the black blood" and thereby renew their life; but in ceremonies of purification they demand polluted water, the "offscourings," and why? The reason is clear. The victim is a surrogate for the polluted suppliant, the blood is put upon him that he may be identified with the victim, the ghost is deceived and placated.

She also draws attention to the passage in Hecuba of Euripides in regard to a matter which has its own interests for us. she says that

In the Hecuba of Euripides, Neoptolemos takes Polyxena by the hand and leads her to the top of the mound, pours libations to his father, praying him to accept the "soothing draughts," and then cries:

Come thou and drink the maiden's blood
Black and unmixed.

I can not pretend to say that the thought here can be anything but the assumption that Achilles' ghost may absorb

[1] Abbott, Evelyn, "History of Greece," New York, G. P. Putnam's Sons, 1888, pt. 1.

[2] Harrison, Jane Ellen, "Prolegomena to the Study of Greek Religion," Cambridge Univ. Press, 1903.

enough of the vital energy to allow him to go comfortably to join the shades below—a journey which in life he had no taste for, saying he would rather be the humblest slave on earth than associate with such unsubstantial company. Nevertheless, though it may have no meaning of sympathetic magic it is easy to see that the "blood is the life." It was not only human blood that was grateful to the ghosts. Odysseus in the Odyssey (XI., 25–50) says, according to the translation of Butcher and Lang,

> when I had besought the tribes of the dead with vows and prayers, I took the sheep and cut their throats over the trench, and the dark blood flowed forth, and lo, the spirits of the dead that be departed gathered there from out of Erebus. Brides and youths unwed, and old men of many and evil days, and tender maidens with grief yet fresh at heart; and many there were, wounded with bronze-shod spears, men slain in fight with their bloody mail about them. And these many ghosts flocked together from every side about the trench with a wondrous cry,

but he would not let them approach. In the Odyssey there is no sacrifice as in the Iliad of young men and maids. Human sacrifices, I think, can hardly be demonstrated always to be associated with or to be a relic of cannibalism, but since the latter practise is only of secondary interest we may turn to that form of it which was associated with homeopathic magic, the predecessor in human thought of the doctrines of Hahnemann. It is not only savage vengeance which Achilles breathes forth as he sees Hector, his prostrate foe, gasping at his feet—it is not only of his friend Patroclus, who fell by Hector's hand, that he thinks, it is ardent admiration for Hector's virtues which he supposes can be thus absorbed. Chapman's translation[3] runs thus:

> I would to God that any rage would let me eat thee raw,
> Slic't into pieces, so beyond the right of any law
> I taste thy merits!

This, though in the Iliad, is primitive enough. This is an indiscriminate appetite for all the virtues, but we can easily find indications that the passions have different seats. "Life," for which we can nearly always substitute "soul" as the conceptions if not identical are usually confused, we easily find in the blood.

While it is necessary to differentiate the historical, the archeological Troy from Homeric Troy, chiefly we are concerned with Homer, or rather with a number of Homers traveling up and down the littoral of Asia Minor for two or three

[3] Chapman, George, "The Iliads of Homer," tr. according to the Greek, by George Chapman.

hundred years after the catastrophe at Troy. So far as we can make out, most of the six or more cities, which were erected at different widely separated epochs on the site of Priam's city, were built there for—not to use a harsh word—commercial purposes—to levy toll on the merchandise which could not get through the rushing tide of the Bosphorus. Anger naturally arose among the people who would have liked to pass their mule trains overland free of tax, so successive cities rose and fell where Schliemann only looked for the one Homer wrote about. Now to suppose that such a center for all the roaring trade of the ancient civilizations, with the Black Sea outskirts of the Ægean, knew nothing of Babylonian magic is not reasonable. It was a cosmopolitan city even on Homer's showing. Diverse tribes were here allies. Memnon, a black man of the plains, married a light-haired woman from the mountains and led a dusky contingent to Troy. Hecuba, Priam's queen, was Phrygian. A piece of jade from far-away China was one of the things found in the ruins, etc. The latter perhaps is the most suggestive, because it is best authenticated. We might discard half the myths that point to the political status of ancient Troy, as archeologists now conceive it and there would still be left a respectable number. The persistence of the repetitions of city building on that site looking out over the Hellespont at the baffled vessels trying to stem the current which has upset the calculations of the master pilots on the super dreadnoughts of our day, presses for the obvious interpretation. That stone which only China can furnish speaks volumes.

At Troy there are the remains of no less than six cities one above the other. There was a great city there in 2000 B.C., the second of the series. Even in the second city there was discovered a fragment of white nephrite, a rare stone not found anywhere nearer than China, and testifying to the distance which trade could travel by slow and unconscious routes in early times.[4]

So if Homer was ignorant of Babylonian magic or even of Malay magic it is because these particular varieties did not leave the caravans much, that wore the paths across Syria or the ships that passed by sea along her shore, not because oriental magic was not known to the real Trojans. There were things about Troy Homer did not know or that his audience were not interested in.

In the Iliad Homer wrote for those not interested in, and he himself there shows himself not much concerned with the

[4] **Murray, Gilbert, "Rise of the Greek Epic," Oxford, Clarendon Press, 1911.**

black man's magic, except as it concerned drugs. It would seem, however, if they had their knowledge of drugs from Egypt, they must have had to take with them much of the magic which rendered them efficacious, but Nestor in the Iliad said he had met in his youth Agamede and she, though not an Egyptian, "knew all drugs that the world nourisheth" (XI., 739). We may be privileged to doubt this, but we can see in the verse at least the indication that woman among the primitive Greeks took as naturally to herbs as she did among the hardy frontiers men in our early times. In the Odyssey, however, we find the fair Helen mixing a potion for Telemachus, in which some commentators see a hint of opium from Egypt, for

she cast a drug into the wine whereof they drank, a drug to lull all pain and anger, and bring forgetfulness of every sorrow. Whoso should drink a draught thereof, when it is mingled in the bowl, on that day he would let no tear fall down his cheeks, not though his mother and his father died, not though men slew his brother or dear son with the sword before his face, and his own eyes beheld it. Medicines of such virtue and so helpful had the daughter of Zeus, which Polydamna, the wife of Thon, had given her, *a woman of Egypt*, where earth the grain-giver yields herbs in greatest plenty, many that are healing in the cup, and many baneful. There each man is a leech skilled beyond all human kind; yea, for they are of the race of Pæon. (Odyssey IV., 230.)[5]

Where Circe's enchanted isle was we do not know, but the metamorphoses of the friends of Odysseus into swine and the love philters make us think it may have been an appendage of some Oriental country. At least we can see in the incident the bent of mind of the Mediterranean race rather than northern transformations. Eurylochus tells him:

Thy company yonder in the hall of Circe are penned in the guise of swine, in their deep lairs abiding. Is it in hope to free them that thou art come hither? Nay, methinks, thou thyself shalt never return but remain there with the others. Come, then, I will redeem thee from thy distress, and bring deliverance. Lo, take this herb of virtue, and go to the dwelling of Circe, that it may keep from thy head the evil day. And I will tell thee all the magic sleight of Circe. She will mix thee a potion and cast drugs into the mess; but not even so shall she be able to enchant thee; so helpful is this charmed herb that I shall give thee, and I will tell thee all. (Odyssey X., 275.) "Therewith the slayer of Argos gave me the plant that he had plucked from the ground, and he showed me the growth thereof. It was black at the root, but the flower was like to milk. Moly the gods call it, but it is hard for mortal men to dig; howbeit with the gods all things are possible."

She had so overcome his comrades with

"a mess of cheese and barley-meal and yellow honey with Pramnian wine,

[5] Butcher and Lang, "The Odyssey of Homer," done into English prose by S. H. Butcher, M.A., and A. Lang, M.A.

and mixed harmful drugs with the food to make them utterly forget their own country."

So the commentators again think of Egypt and opium and we may think at least in the Odyssey of Oriental magic. Indeed the story has been traced to Babylon,[6] but it is not necessary for us to believe it was anything but an indigenous story of the brown race.

The myth of the Harpies is told in connection with Phineus, the son of Agenor, one of the Homeric heroes, but though placed later than the Iliad, one of them is mentioned there (XVI., 150). I do not know as to the authenticity and the chronology of this passage, but in Hesiod and Theognis they appear. I think there can be no doubt they are lineal descendants of the creatures that carried the souls of Pharaoh's dead subjects around their tombs. They have only the incidental interest for us that we feel in the idea of the winged soul, the pneuma, the spiritual aspirations of man, the uplift of man to higher things, etc., but here they have an interest in bearing the impress of Mediterranean magic, perhaps combined with some northern myth, for Podarge, one of the three, was the dam of Achilles steeds sired by the West Wind. Other hints incidentally appear even in the Homeric epics of this intrusion of Mediterranean magic.

So far as we have gone on our own path it is evident that Keller[7] is justified in his conjecture that it is

with Phoenicians and their tales are probably to be associated the monsters of Homer: the Chimaera, a composite of lion, serpent, and goat, slain by the hero Bellerophon, the Gorgon's head, Scylla and Charybdis, the Sirens, etc., as well as the savage tribes so vaguely located about the world.

A small amount doubtless was imported magic, a certain amount the northmen brought with them, a certain amount they found indigenous in the Ægean area which may have been specific to certain localities, but we can scarcely go far wrong in believing that much the larger amount was a magic common to all primitive men at the stage of culture represented by Homer's Greeks. One of these traits we know is homeopathic or sympathetic magic, a very comprehensive division, yet so far as it is to be noted in affiliation with medicine it is scarcely to be found. We have seen Achilles desiring to eat Hector's flesh in order to get the virtues of his foe, but it is in the story of Telephus, which seems to have been preserved chiefly by Strabo, we get the most perfect exemplification of it. Euripides wrote

[6] "Encyclopædia Brittanica," Article —, "Circe," 11th ed.

[7] Keller, Albert Galloway, "Homeric Society," Longman, Green & Co., New York, 1913.

a play from the legend which had been lost. Plutarch[8] ("Morals," Vol. I., 289), Pliny[9] (XXXIV., 15) and Cicero[10] (Pro L. Flacco C., 29) and Pausanias[11] all refer to it. He married one of Priam's daughters, but he does not appear in any of the texts of the Homeric poems which have come down to us. He was severely wounded by Achilles and finally on the advice of an oracle came to Greece and presented himself to Achilles, who healed him by applying to the wound scrapings of the spear with which the wound had been inflicted. Presumably the legend grew out of the Homeric poems by the influence of a magic which it is hard to believe was not prevalent in Homeric medicine, and Grote[12] remarks that Strabo pays little attention to any portion of the Trojan war not found in the Homeric poems proper, and appears not to have read Arktinus, but he may have derived it from some equally ancient author. At any rate, even in the Roman development of Greek medicine it was a spur to homeopathic practise. Philostratus[13] tells how Apollonius cured a boy from a mad dog's bite, by sending the dog into the river and so curing it, whereon the bitten boy also recovered. "He said: 'The soul of Telephus of Mysia has been transferred into this boy, and the Fates impose the same things upon him as upon Telephus.'"

We are thrown therefore by the internal evidence of the poems themselves on the assumption that the author of the Iliad wrote in an atmosphere appreciably different from that of the author of the Odyssey. Quite independent of this internal evidence is the view that as northern blood poured into the Mediterranean area and gave it, at some date before the rise of the highest culture in Greece, a hue derived from another clime, cosmic influences, including that of disease, was at once at work to tap this foreign stream and finally to banish it through its lack of adaptation to the environment. Gradually the Northman died out and the Mediterranean race and its culture, at first submerged by the invasion, came again into its own. The date of the fourteenth century B.C. finds Egyptian influence still dominant on the mainland of Greece, or rather

[8] Plutarch, "How to Profit by our Enemies," Morals: Tr. from the Greek by Wm. W. Goodwin, 1820, Vol. 1, 289.

[9] Plinii, C., "Secundi: Naturales Historiæ," Lib. 11, XXXVII., Sect. 70, Silig, p. 300.

[10] Cicero, "De Natura deorum," III., 22. Teubner, 1890, pt. 4, Vol. 2.

[11] Pausanias, "Description of Greece," tr. by J. G. Frazer, London, Macmillan & Co., 1898.

[12] Grote, George, "History of Greece," Part 2, Ch. 15.

[13] Philostratus, "Flavius: The Life of Apollonius of Tyana," tr. by F. C. Conybeare, Vol. 2, Bk. 6, p. 143, London, Wm. Henilmann, 1912.

we are to suppose that it was more properly an Ægean than a strictly Egyptian culture. Sir Arthur Evans[14] of late has shown himself more and more inclined to limit the antiquity of the Northmen in the Ægean to some such epoch, for it is not the yellow-haired men but the brown-complexioned race, or the red men with high artistic capacities which are shown in the wall pictures, and he intimates that this artistic temperament was due to the blood of the Mediterranean race which finally predominated in the Ægean. The light-skinned people evidently came in and conquered in battle, but in the long run the race which had the traditions of African magic in its heredity came to the surface. "It is true that the problem would be much simplified if we could accept the conclusion that the representatives of the earlier Minoan civilization in Crete and of its Mycenæan outgrowth on the mainland were themselves of Hellenic stock." There is nothing which now seems improbable much less impossible in this commonly accepted view, but it lacks desirable confirmation.

Doubtless some of these elements, notably in Crete, were absorbed by later Greek cult, but their characteristic form has nothing to do with the traditions of primitive Aryan religion. They are essentially non-Hellenic.

The period during which these Northmen were dominant begins according to Evans not earlier than the twelfth century and even in Hesiod's Theogony, five hundred years later, we find the trace of Set, Horus and Osiris in the spirit if not in the literal similarity of the myths. There is, it must be confessed, considerable ground for Evans' remark that "in the end, though the language was Greek, the physical characteristic of the later Hellenes prove that the old Mediterranean element showed the greater vitality." It was the brown race largely tinctured with the ideas of the African and the Asiatic. Enough has now been said to begin the attempt at the differentiation of the white man's magic from that of the brown man and the black man, the yellow man and the red man.

When we find the African chief soliciting the aid of invisible powers by hanging various articles on a blasted tree trunk or muttering words we do not understand to his block of wood or pieces of stone, we say this is magic. When we see in a Greek façade figures pleasing to our eyes grouped in what is to us artistic fashion, around a graceful altar from which the smoke of slaughtered goats ascends to heaven with that of the faggots of the fire, we say this is *art*.

[14] Evans, Arthur J., "The Minoan and Mycenæan Element in Helenic Life," *Journal of Hellenic Studies*, 1912, Vol. 32, pp. 277, 287.

When the African chief's medicine man tells him of the strange creature with horns and great round red eyes which his incantations have raised from the river's mud, we say this is magic, but when we read of the gray-eyed Athena plucking one of her heroes by the sleeve or by the hair invisible to all eyes but his, we say this is poetry, and when the details of hair and garment folds, of blowing winds and clouds in the sky are sketched for us, we say this is realism. Now I do not know what the evolved African chief or the Malay prince might say it is, with only his social heredity behind him, but I suspect he would say, why *this* is magic. Now I imagine something of this kind of subjectivity troubles our Homer critics. They can not shake off from themselves their social heredity. The various epiphanies of gods and goddesses on the battle field or in council have their "magic" for us, but we usually say "charm" and with the connotation of the two words we should set ourselves right. When Athena brushes aside like troublesome flies, the spears and arrows aimed at her protégé, we don't think at all of negro "magic" but of the "*charm*" of the white man's poet. Of course I might continue indefinitely thus to outline from the incidents in the Homeric poems illustrations of the reason I conceive why the northman critic finds so little magic in the northman poet's lines. This might be interesting but it would be exhaustive of space, and the chief thing for us in the lesson I am endeavoring to shadow forth is that it *was* northern magic, it *was* a new race coming in and remaining undefiled by southern magic for awhile that makes the northern critic, unable to pull himself up by his boot straps, unable to see the magic of his ancestor. There is some magic which we recognize as such in the Iliad and much more in the Odyssey and were we to add to it the magic we do not recognize on account of its "charm" the balance sheet between the African or Malay ledger and that of the Scythian from beyond the Danube would not show great discrepancy in the totals.

If there is a flaw in this argument, and I suppose there must be many of them, it is as to medical magic. Where are the incantations and the invocations, the beating of the tom-tom, the swinging of censers and the general chase after the soul and the flight from the disease devils and demons of Babylonia and Malaysia, the witches of the Congo and the Nile? There are not many of them in the Iliad and the Odyssey does not swarm with them as do the Zend Avesta and the Atharva Veda. But the malicious northern demons of disease are not there either and it really seems as though the argument I have adduced, if

it is worth anything at all, is applicable rather to magic in general than to medical magic. To this the answer is that neither the Iliad nor the Odyssey is a hospital history book nor the records of the health office, both phenomena of a static common wealth when we find them on our book shelves. These poems are annals of war and the itinerary of an adventurous traveller, full of wiles and lies but not interested even in surgery beyond wounds by sea and land and the occasional pestilence which halts the march of armies and is the stoled priest's business anyhow. The Atharva Veda and the Zend Avesta are the priests' own books, the Iliad and the Odyssey are those of the warrior and the soldier of fortune.

We may perhaps see in the Iliad in the sacrifice of horses attributed to the Trojans by Achilles (XXI., 131), a custom Xerxes followed when he passed the Nine Ways on his invasion to Greece as told by Herodotus (VII., 112), the same sacrifice being repeated by Mithridates and Sextus Pompeius,[15] but we may conjecture this was a custom the Northmen, including the Aryans, acquired before they entered the basin of the Mediterranean.

To the attentive reader of the Rig Veda which is claimed as more distinctly Aryan in origin and feeling it, like the Iliad, will seem to hold little we call magic and much we call charm or poetry. The Atharva Veda, a much later composition, is full of magic. In the argument as I have presented it for the Greek poems, the Vedic hymns would furnish parallel evidence.

[15] Seymour, Thomas Day, "Life in the Homeric Age," New York, The Macmillan Co., 1914.

THE ORIGINS OF CIVILIZATION[1]

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FROM THE OLD STONE AGE TO THE DAWN OF CIVILIZATION. III

SUCH forces gradually brought about the union of two states on the Nile: in the *north* a kingdom of the delta commonly known as Lower Egypt; and in the *south* a kingdom of the valley above the delta, which we usually call Upper Egypt. The kingdom of Upper Egypt was evidently the older. Side by side the two existed for centuries, each gaining its own traditions, symbols and insignia which survived in historic times for thousands of years. In early dynastic reliefs like Fig. 41, we see

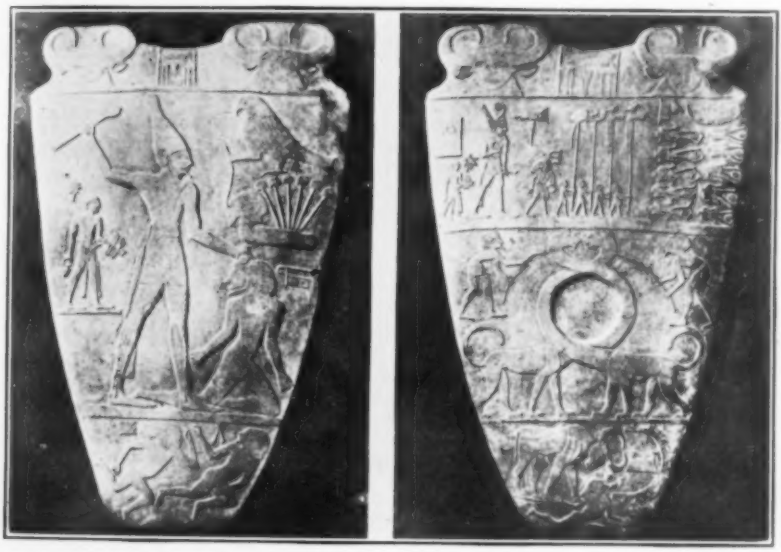

FIG. 41. TRIUMPH OF A PHARAOH AT THE BEGINNING OF THE DYNASTIC AGE. On the right, the king wears the white crown of Upper Egypt; on the left (top scene, left end) he wears the spiral-crowned diadem of Lower Egypt. Relief scenes on a magnificent ceremonial palette of slate. (From Quibell, "Hierakonpolis.")

the tall white crown worn by the prehistoric kings of Upper Egypt, and also the curious spiral-crowned red diadem which regularly distinguished the King of Lower Egypt. In a prehistoric struggle which must have gone on for generations, the king of Upper Egypt, he of the tall white crown, conquered his

northern rival of Lower Egypt, him of the curious red crown, and united Egypt under one sovereignty. Thus probably not more than a century after the middle of the fourth millennium B.C., emerged the first great state in history. In commemoration of his double sovereignty over the two prehistoric kingdoms, the Pharaoh, as we may begin to call him, assumed and wore the crowns of both states, as we see this king here doing on two different occasions. It is interesting to find him still wearing the symbol of his hunting ancestry—the tail of a wild animal appended to his girdle behind.

Such monuments as these show us how the prehistoric Egyptian system of picture signs was developing into phonetic writing. The victory of this king over the enemy symbolized by this single adversary whom he is shown dispatching (Fig. 41, right-hand relief), is commemorated in an archaic pictographic group over the head of the captive. The falcon (here with a human arm) is an enormously old symbol of the prehistoric ruler of upper Egypt. Knowing this, we easily read the group; for it will be noticed that the falcon grasps a rope by which he leads a captive suggested by a human head with the rope fastened to the mouth. This head rises out of a stretch of level ground out of which are growing six lotus leaves on tall stems each the symbol for 1000. Just below is a single barbed harpoon, and a small rectangle filled with wavy lines of water, meaning a pool or lake. The meaning of the whole is clear: "The Falcon King has led captive 6,000 men of the Land of the Harpoon Lake." The further process by which these purely picture signs became phonetic, furnishing the earliest known system of phonetic writing, is now fairly clear to us, but space will not permit its discussion here. It should be mentioned, however, that before 3000 B.C. this system of Egyptian writing developed a complete series of consonantal alphabetic signs, and there is now no reason to doubt that the Phœnician alphabet, and hence likewise our own, have descended from the picture writing of Egypt which we have just read. This question will be taken up more fully in discussing the Phœnicians.

It is of importance at this point to remember that the exclusively Nilotic origin of Egyptian writing is easily demonstrable. In view of this fact it is quite inexplicable that there should have been a wide-spread impression that it was of Asiatic origin. In the first place our oldest examples of Egyptian writing are older than the earliest known writing of Asia. Furthermore Egyptian writing is a veritable zoological and botanical garden of fauna and flora unmistakably Nilotic, while it includes also an extensive museum of implements, ap-

pliances, weapons, clothing, adornments, buildings, etc., peculiar to the Nile valley. Only lack of acquaintance with the material background of Egyptian life, and a failure to study carefully the content of the Egyptian sign lists, can account for the totally groundles assertion of the Asiatic origin of Egyptian writing by Hommel and de Morgan, which has unfortunately found its way into many current books. As his writing developed, the Egyptian at the same time devised the earliest known paper, which he succeeded in making from the papyrus reed

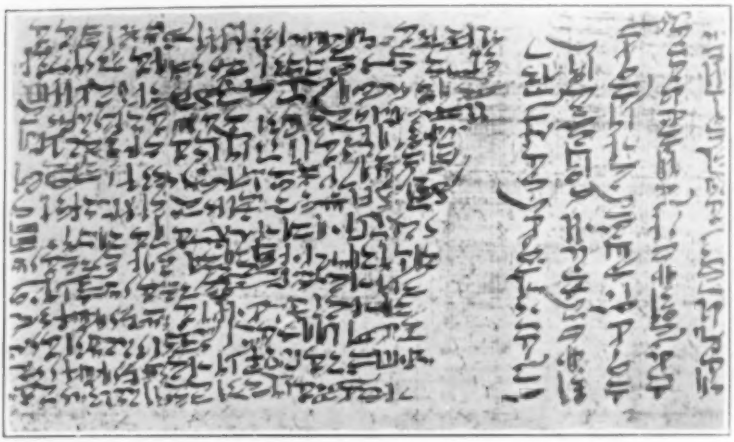

FIG. 42. SPECIMEN OF EGYPTIAN PAPYRUS PAPER, CONTAINING PART OF A TALE WRITTEN NEARLY 2000 B.C. Now in the Berlin Museum.

(*Cyperus papyrus*), a plant which grew very plentifully in the Nile marshes (Fig. 42). It has especial interest for us, because it was the first paper used by Europe, and as we shall see, this paper brought to Europe an alphabet which had grown up out of the system of Egyptian hieroglyphic of which we have just been speaking.

Thus emerged the first great organization of men, efficient in the possession of a system of written records and communication, and stably founded on a basis of agriculture and cattle breeding, prepared to exploit to the full the possession of metal tools. It was now that the kingship proved invaluable in furnishing the powerful organization for mining on a large scale which private initiative could not have furnished. The source of copper was in the Peninsula of Sinai.

Berthelot has remarked[20] how interesting it is, that probably at the beginning of the exploitation of these mines of

[20] "Sur les mines de cuivre du Sinai," *Comptes rendus de l'Académie des Sciences*, 19 Aug., 1896.

FIG. 44. ONE OF THE EARLY COPPER MINES IN SINAI WORKED BY THE ANCIENT EGYPTIANS. (Photograph by Petrie.)

Sinai, that is over six thousand years ago, by an empiricism the origin of which is easy to conceive, man had already gained the processes for smelting metal, which have been followed ever since even down into our own day. Only recently have the metallurgical chemists succeeded in devising processes more successful and efficient than those which were first devised in Sinai over six thousand years ago.

This remark of Berthelot's justifies us in picturing the experience of some wandering Egyptian back in the fifth millennium B.C. as he banked his fire with pieces of copper ore which happened to be lying about his camp—part of the talus and detritus which encumbers the base of the cliffs in the lonely valleys of Sinai. As these natural fragments were exposed to the fire, the charcoal of the wood blaze, together with the heat, reduced a portion of the ore, and we can easily imagine how the attention of the wanderer would be attracted by a glittering globule of the liberated metal as it rolled out among the ashes.

The new age of mankind born on that memorable day was beginning to enter on its birthright, when centuries later the Egyptian monarchy emerged in the middle of the fourth millennium B.C. The metal, which the first Egyptian who possessed it had gained by accident, was now to be won systematically and on a relatively large scale, as only the sovereign could do in that distant age, when individual initiative was unequal to

the task. In Fig. 44 we see one of the ancient Egyptian mines in Sinai visible high up on the right. Though this particular example is not one of the earliest, these mines of Sinaitic Maghara are the oldest known mines in the world. Below the mine on a slight elevation at the foot of the slope we see the stone huts of the miners. A protective wall extends transversely across the valley. Here lived a little colony of miners. Plentiful evidences of their work are still scattered about the place. Under the floor of the hut they concealed the pottery canteen with which they carried on their rough-and-ready housekeeping, and there Petrie found it in his investigation of the place (Fig. 45). Their copper tools have likewise been found covered by rubbish (Fig. 46). The heavy stone picks which they still employed in getting out the ore, have likewise been found on the spot (Fig. 47).

The interiors of the mines themselves are very instructive. The action of the copper tools on the wall of the drift can still be closely followed and exhaustively examined, even to deter-

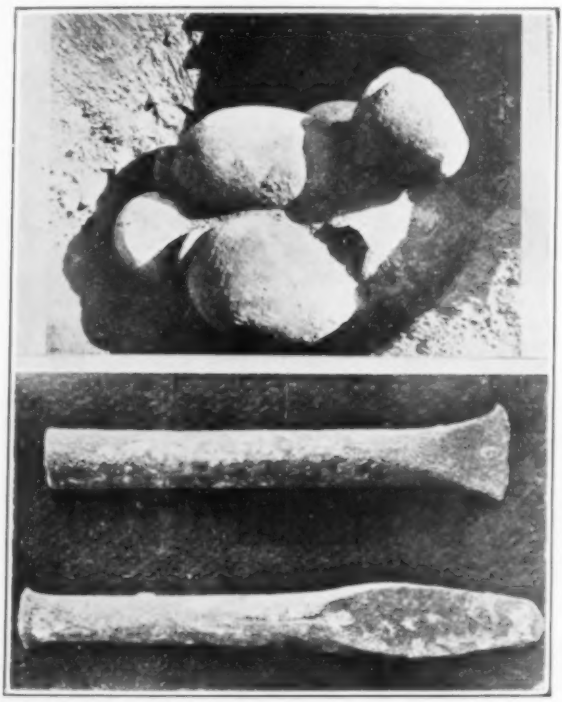

FIG. 45. POTTERY CANTEEN OF ANCIENT EGYPTIAN MINERS. Found buried under the floor of their hut in Sinai. (Maghara; photograph by Petrie.)

FIG. 46. COPPER CHISELS EMPLOYED BY ANCIENT EGYPTIAN MINERS IN SINAI. (Serabit; photograph by Petrie.)

FIG. 47. HEAVY STONE PICKS AND STONE DRILL-HEAD FOUND AT ANCIENT EGYPTIAN COPPER MINES IN SINAI. (Photograph by Petrie.)

mining the width of the chisel edge (Fig. 48). Though the mines are not usually large, and do not commonly exceed five feet in height, Fig. 49 shows a chamber of spacious dimensions. Space does not permit discussing the methods of freeing and taking out the ore; but we may glance at the evidences which disclose the smelting process. It is clear that smelting was often done directly at the mine. Petrie found the heavy stone pounders by means of which the ore was crushed (Fig. 50). Masses of slag have also been uncovered, and in Fig. 51 we see

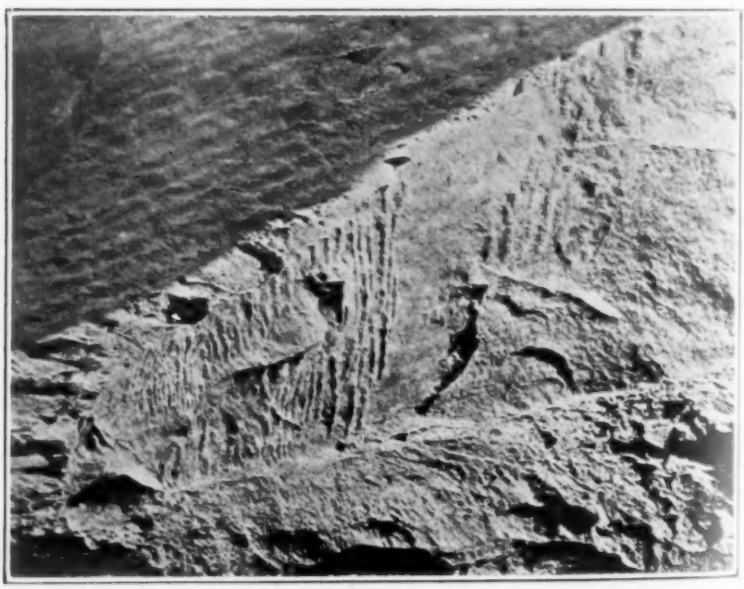

FIG. 48. WALL SHOWING STROKES OF COPPER CHISEL IN ANCIENT EGYPTIAN COPPER MINE IN SINAI. (Maghara; photograph by Petrie.)

a pottery crucible with large nozzle for pouring the molten metal into forms.[21]

The copper-bearing minerals which these earliest miners smelted were chiefly of three kinds: turquoise, containing only about three and a third per cent. of oxide of copper; a hydrosilicate of copper; and finally certain granites impregnated with carbonate and hydrosilicate of copper. These granites are also poor ore, but the hydrosilicate is sometimes very rich in copper.[22]

FIG. 49. INTERIOR OF A LARGE COPPER MINE WORKED BY THE ANCIENT EGYPTIANS IN SINAI. (Serabît; photograph by Petrie.)

The decisive importance of these mines in Sinai is evident when we understand that they are definitely dated. For over two thousand years the Pharaohs exploited the Sinai copper regions and have left their records on the rocks around the mines to testify to the fact. These records begin in the thirty-fourth century and continue until the latter part of the twelfth century B.C. It is not a little impressive at the present day to see appearing on the rocks before us the figure of the first ruler of men who has put himself on record as having organized and sent forth his people to bring out of the earth the metallic re-

[21] The above discussion of the ancient mines of Sinai is much indebted to the text and photographs of Petrie, "Sinai."

[22] See Berthelot, *ibid.*

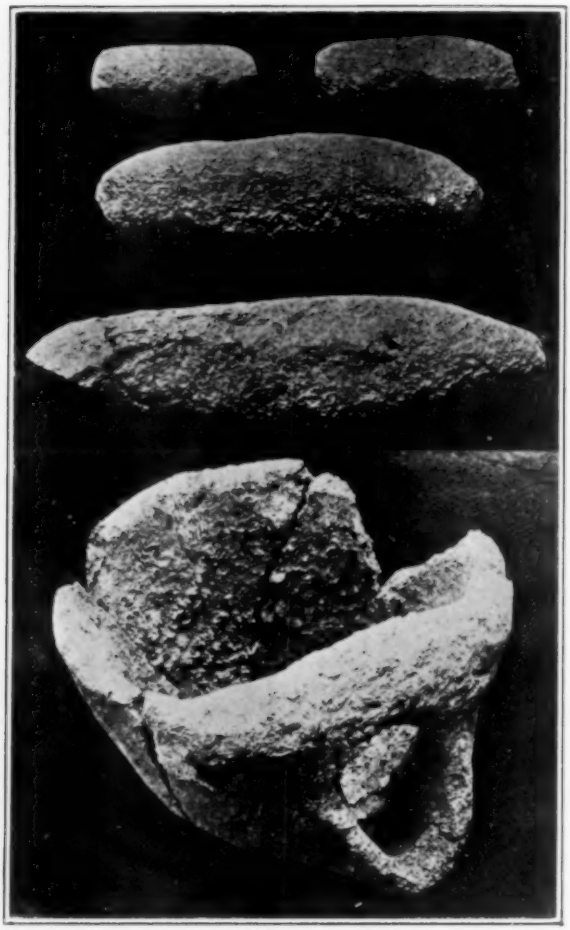

FIG. 50. STONE POUNDERS FOR CRUSHING COPPER ORE USED BY THE ANCIENT EGYPTIANS IN SINAI. (Photograph by Petrie.)

FIG. 51. POTTERY CRUCIBLE WITH NOZZLE FOR POURING MOLTEN COPPER INTO FORMS. Found at the ancient copper mines in Sinai. (Serabit; photograph by Petrie.)

sources without which man could no longer carry on a great state (Fig. 52).

As we approach we are standing in the presence of the earliest known historical monument. Carved with rugged and archaic simplicity, the figure of this earliest royal miner rises before us in heroic proportions. Here is the earliest sovereign to follow economic dictates and to march into a neighboring continent to seize by sole right of might the mineral wealth which his people needed. Depicted in the symbolic ceremony of crushing the Bedwi chief of the district, to signify the Egyptian Pharaoh's possession of the region, this king Semerkhet

thus published to the natives of western Asia his sovereignty over the world's earliest copper mines. He wears here the official crowns, the white and the red, which signify his supremacy over the Two Egypts, a supremacy which he had thus extended over neighboring Asia in the 34th century B.C. Thus the earliest known autocracy, seizing the mineral-bearing regions of Asia which it needed, some 5,300 years ago, began that long career of aggression based on economic grounds, which continuing ever since culminated in the seizure of the mineral wealth of northern France in August, 1914.

This record of Egyptian conquest in metallurgy, let it be noted, consists of inscriptional as well as sculptured elements. The name of the king in Egyptian hieroglyphics of unmistakable Nilotic origin, accompanies his figure, and it is well to remember that this mining record, made after Egypt had known of copper for over half a millenium, is nevertheless several centuries older than the oldest dated piece of copper known in Asia.

This earliest family of sovereigns ruling over a people of several millions was founded about 3400 B.C. by Menes, the first of the Pharaohs. His home was at Thinis, near Abydos in Upper Egypt, below the great bend where the river approaches most nearly to the Red Sea. We call the whole group the First Dynasty, and together with the second group, or second Dynasty, these early dynastic kings of Egypt were

FIG. 52. RELIEF CARVED ON ROCKS AT THE ANCIENT EGYPTIAN COPPER MINES IN SINAI (MAGHARA), IN THE THIRTY-FOURTH CENTURY B.C. It shows the figure of the earliest known mining promoter, King Semer-khet of Egypt. At the left he smites a Bedwi chief of the region, while his other two portraits display him once with the crown of Upper and again with the crown of Lower Egypt. This is the oldest historical monument known, and the earliest such record of a foreign conquest on alien soil. (Photograph by Petrie.)

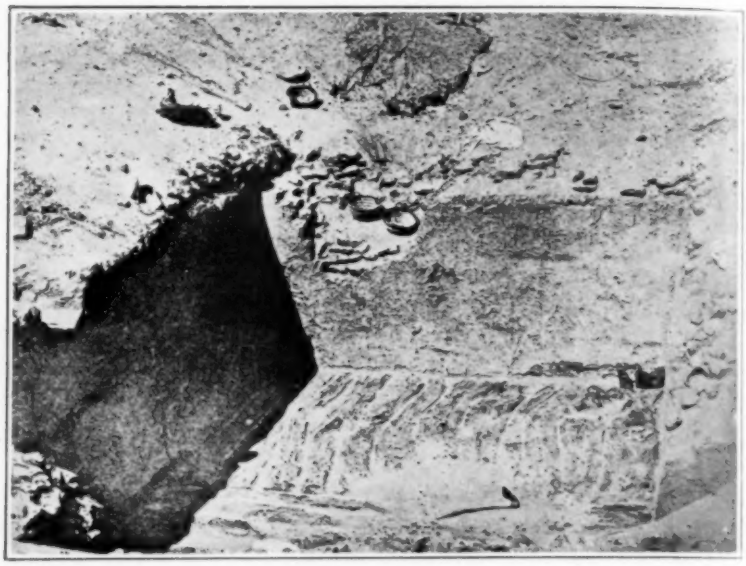

FIG. 54. BRICK-LINED TOMB CHAMBER OF ONE OF THE EARLY DYNASTIC KINGS (ABOUT 3400 TO 3000 B.C.) AT ABYDOS. (Photograph by Petrie.)

buried in the desert behind Abydos, where the wreckage of nine of their tombs still survives (Fig. 54). After Amélineau's unsuccessful and destructive attempt to excavate these

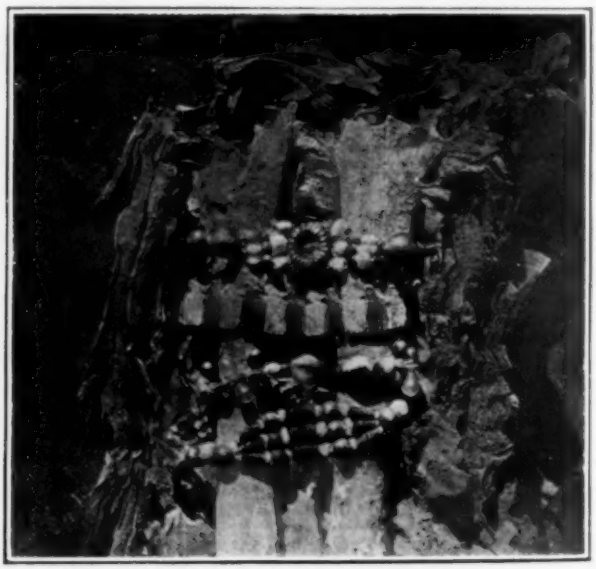

FIG. 55. FOUR BRACELETS OF GOLD AND PRECIOUS STONES, STILL ON THE ARM OF A ROYAL LADY. Found by Petrie in one of the early dynastic tombs of Abydos. (Photograph by Petrie.)

tombs, we owe the rescue of what was left, to Petrie's efforts. He was able to save enough of the palace furniture and other royal equipment placed in these tombs for the use of the royal dead in the hereafter, to disclose to us the remarkable progress of this earliest state in material life, especially in arts, industries and craftsmanship, during the last four centuries of the fourth millennium B.C., that is about 3400 to 3000 B.C.

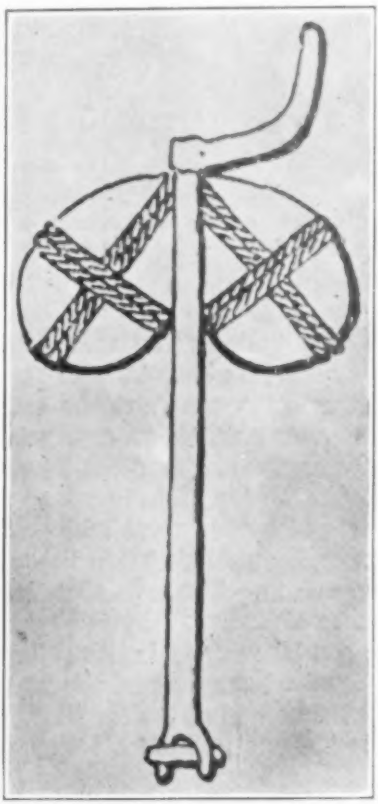

FIG. 56. EGYPTIAN CRANK DRILL INVENTED IN THE EARLY DYNASTIC PERIOD (ABOUT 3400 TO 3000 B.C.), THE EARLIEST KNOWN MACHINE. (Drawn by Borchardt from a hieroglyph.)

The advance in industrial appliances of which the jewelry in Fig. 55 gives evidence, is illustrated by a very important device for drilling out stone vessels, which was invented in the early dynastic period (Fig. 56). It is elaborately drawn for us in hieroglyphic, in which it became the sign for "craftsman." It consists of a vertical shaft with a crank attached at the top, and forked at the base to receive a cutting edge in the form of a sharp stone. Just below the crank are attached two stone

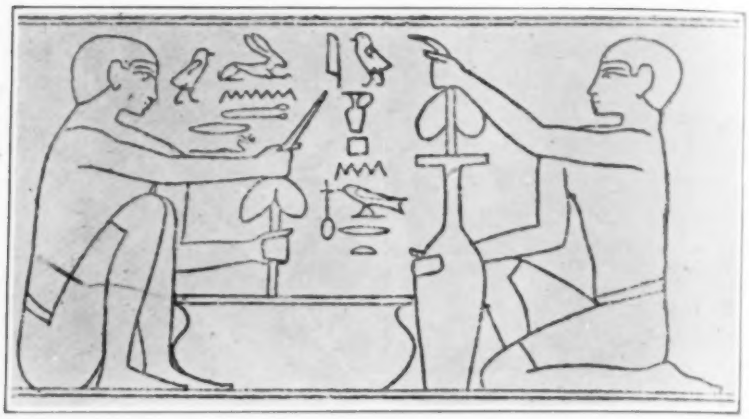

FIG. 57. EGYPTIAN CRAFTSMEN ENGAGED IN DRILLING OUT STONE VESSELS WITH THE CRANK DRILL SEEN IN FIG. 56. The scene is taken from a tomb relief. The hieroglyphs between the two workmen record their conversation. One says: "This is a very beautiful vase." The other responds: "It is indeed." (From de Morgan, "Recherches sur les origines de l'Égypte," I.)

weights, like the two balls of a steam governor. These of course serve as a fly wheel to keep the shaft revolving. Here is the earliest machine which can fairly be called such. It displays the earliest known crank or crank-driven shaft. The result was superb stone vessels and the development of a new and highly refined craft (Fig. 57).

Stimulated perhaps by his rival who was producing such beautiful stone vases, the potter at this time also made a great advance in his ancient art. For ages, since his ancestors of the lower alluvium, who already lay buried many feet below the potter's yard, he had laboriously built up his vessels by hand. But now he perfected what was perhaps at first merely a revolving bench, till it emerged as the familiar potter's wheel, the ancestor of the lathe, upon which his clay vessels were now turned.

Thus before 3000 B.C. Egyptian craftsmen devised two revolving machines, involving the essential principle of the wheel, with a *vertical* axis; but the wheel as a *burden-bearing device* with a *horizontal* axis (unless as employed in the pulley block?) did not arise in Egypt. It was first used in Asia. On the basis of these devices, and a long list of metal tools highly specialized, there arose a large group of sharply differentiated crafts, among which was the important art of glaze-making, the forerunner of the first production of glass. All these crafts were carried on by the first great body of *industrial* population known in history. They were in existence before 3000 B.C.

The great African game preserve at the southeast corner of

the Mediterranean, which once supported only detached groups of hunters wandering through the jungle, had become a huge social laboratory, where these Stone Age hunters had been transformed first into plowmen and shepherds and then into handicraftsmen. In the course of this process civilization arose and gained a stable political basis in the thousand years between 4000 and 3000 B.C.

Thus supported upon an economic foundation of agriculture, animal husbandry and manufacturing industries, arose the first great state on the Mediterranean, indeed the first great state in the world, at a time when all the rest of mankind was still living in Stone Age barbarism. Such a stable fabric of organization, under the power of the old falcon chieftain, once ruler only of Upper Egypt, but now sole head of all the Egyptian people, had shifted man from a struggle with exclusively *natural* forces, into a new arena where he must thenceforth contend with *social* forces, and out of his crucible of social struggle were to issue new values of a different order, like social justice, the value of right conduct, and hopes of happiness beyond the grave based upon worthy character—conceptions in which the Nile dwellers were as far in advance of the world about them as they were in their conquest of the material world.

This extraordinary forward movement of man before 3000 B.C. in the vicinity of the junction between the two continents, Africa and Eurasia, could not go on without important effects on the advance of man in Western Asia. It is evident that here too man had been pushing forward since Paleolithic times, and his ultimate progress in the whole region around the eastern end of the Mediterranean and down the Tigris-Euphrates valley was to have a profound influence on the career of man in the Mediterranean and thus upon the course of general human history.

The chronological relations of the cultures on the Nile and the Euphrates have not yet been definitely determined. Just as in the case of Egypt, so with regard to Babylonia, the excessively remote dates once current have been shown to be untenable. They have been given wide currency by de Morgan and others. De Morgan bases his conclusions upon two bodies of evidence. First the chronology once drawn from the written documents; and second his own excavations at Susa, the leading town in the old Elamite country on the east of Babylonia. Dr. King of the British Museum long ago discovered evidence which showed that the chronology drawn from the written documents which dated King Sargon of Akkad in the thirty-eighth century B.C. was impossible. De Morgan's distinguished

FIG. 60. THE RIVER TERRACES OF THE EUPHRATES, LOOKING EASTWARD ACROSS THE RIVER. About two hundred and fifty miles northwest of Babylon. (Copyright by Underwood & Underwood.)

countryman, Thureau-Dangin, has only in the last few months published a conclusive reconstruction, leaving nothing to be desired in its finality—a reconstruction which places Sargon well this side of 2800 and our earliest written documents of Babylonia hardly earlier than the thirty-first century B.C.

As to de Morgan's earliest periods at Susa, he dates them by their relative depth, that is by the amount of accumulated rubbish over them. Such rubbish produced by the detrition or violent destruction of sun-dried brick buildings, will of course accumulate at a rate variable from site to site and country to country, depending on a wide range of height of the buildings, widely differing thickness of the walls, the varying rapidity of detrition caused by the differing amount of rainfall and the uncertain number of the successive violent destructions. Following de Morgan, R. Pumpelly has made similar calculations for the age of the lower strata in his excavations of the ancient city of Anau in Turkestan. Among other data as a basis, he took the very slow accumulation of such rubbish in Egypt, without taking into consideration the difference in rainfall (Egypt having practically none), the difference in height of buildings and thickness of walls, and the politically sheltered situation of Upper Egyptian cities which exposed them to less

frequent destruction than the cities of Asia.[23] Such calculations have no value.

The development of civilized man on the lower Euphrates had undoubtedly been going on for ages before the date of his earliest surviving written documents (thirty-first century B.C.), but the age of that development has yet to be established; for unfortunately the prehistoric stages of Babylonian culture have not yet been recovered.

The river terraces of the Euphrates, such as we see in Fig. 60 overlooking a beautiful island, have not been investigated geologically, paleontologically or archeologically at all. It is evident that man dwelt between the Euphrates and the Mediterranean in Paleolithic times. His remains and his stone implements may therefore lie under and along these Euphrates terraces as they do along the Nile. They have indeed been found in Palestine and along the Phœnician coast, in caves, so stratified as to leave no doubt of their Paleolithic origin. From these early stages until the earliest written documents on the Babylonian alluvium (about thirty-first century B.C.), we have no evidence for the course of the development in western Asia.

It is, however, already perfectly clear that while the Nile valley made the earlier advance, and was the earliest home of civilization, there was reciprocal influence between the two early cultures on the Nile and the Euphrates. Thus the mace

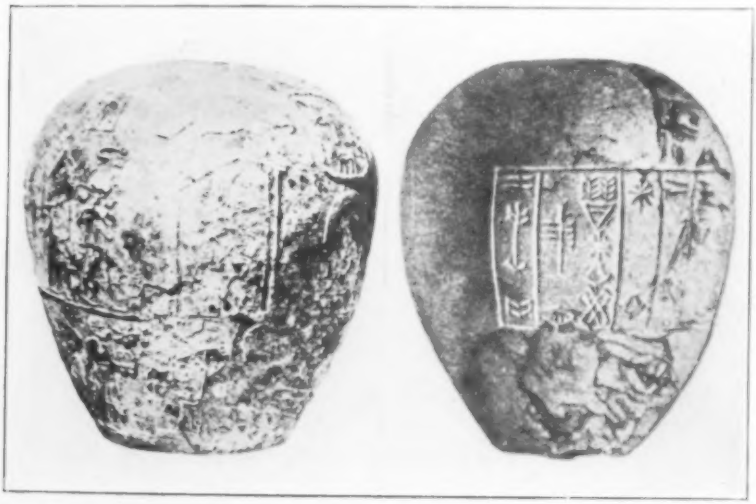

FIG. 61. EGYPTIAN AND BABYLONIAN MACE-HEADS OF THE SAME FORM.

[23] It may be added that Dr. Hubert Schmidt, the able archeologist attached to the Anau excavations, dated the oldest remains found there at about 2000 B.C.

FIG. 62. EGYPTIAN AND BABYLONIAN CYLINDER SEALS OF THE SAME FORM.

head which we find in Egypt far back in the fourth millennium B.C. is also found along the Euphrates many centuries later (Fig. 61). Similarly the cylinder seal employed for sealing clay is found on the Nile centuries earlier than our earliest Babylonian example of it (Fig. 62). The decorative arrangement of balanced animal figures (Fig. 63), especially with a human figure in the middle, is found on the Nile well back

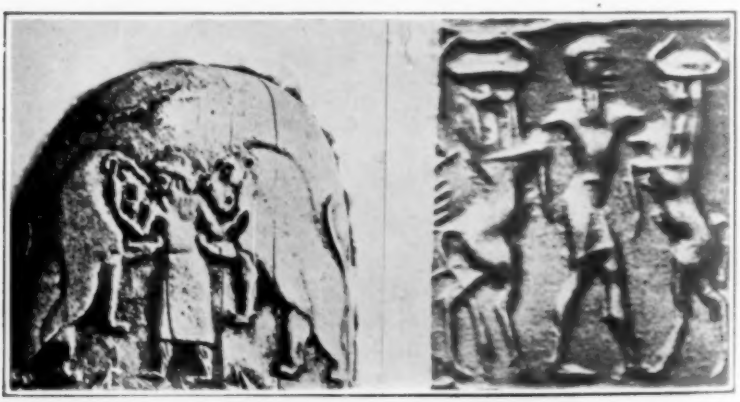

FIG. 63. EGYPTIAN AND BABYLONIAN DECORATIVE DESIGNS. Made up of animal figures balanced antithetically on either side of a human figure.

toward 4000 B.C., and our earliest examples in Babylonia cannot be dated earlier than the thirty-second century B.C. In such matters it should be remembered, however, that an inferior civilization often makes contributions to a superior culture. We have only to remember the source of tobacco, maize, potatoes and the like to illustrate this fact. There will, therefore, have been mutual exchange between the Nile and the Euphrates at a very remote date, and some of these parallels here exhibited may be examples of such mutual interchange.

This process created a great Egypto-Babylonian culture nucleus on both sides of the inter-continental bridge connecting Africa and Eurasia. It brought forth the earliest civilization in the thousand years between 4000 and 3000 B.C., while all the rest of the world continued in Stone Age barbarism or savagery. Then after 3000 B.C. began the diffusion of civilization from the Egypto-Babylonian culture center. The best illustration of what then took place is furnished by our own New World. In only two places on the globe have men advanced unaided from Stone Age barbarism to the possession of agriculture, metal and writing. One of these centers is that which we have been studying here in the Old World; the other is here in the New World.[24] Just as the Egypto-Babylonian culture center grew up at the junction between the two continents, Africa and Eurasia, as the oldest and the original center of civilization in the Old World, so here in the New World the oldest and original center of civilization likewise developed along and on each side of the inter-continental bridge. The far-reaching labors of a great group of Americanists have shown clearly that from this culture center in the inter-continental region of the Western Hemisphere a process of diffusion of civilization went on northward and southward into the two continents of the New World, and that process was still going on when the period of discovery and colonization began. That which we accept as a matter of course as we study the New World center, was obviously going on for thousands of years around the Old World center, although a provincially minded classicism has blinded the world to the facts. It remains for us in the next lecture, therefore, to follow the lines of culture diffusion, diverging from the Egypto-Babylonian group and stimulating Europe and inner Asia to rise from Stone Age barbarism to civilization.

[24] See the present writer's article, "The Place of the Near Orient in the Career of Man, and the Task of the American Orientalist" (presidential address before the American Oriental Society, in *Journ. of the Am. Or. Soc.*, June, 1919).

NATURAL DEATH AND THE DURATION OF LIFE

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I

THE efforts to prolong life have resulted in a diminution of the chances of premature death. Nations with adequately developed facilities for medical research and an efficient public health service have practically eliminated smallpox and typhoid, yellow fever and malaria, and have conquered rabies, diphtheria, tetanus, and cerebrospinal meningitis. If this development continues to receive the support it deserves, the time is bound to come when each human being can be guaranteed with a fair degree of probability a full duration of life. But why must we die?

The French encyclopedists of the eighteenth century defined life as that which resists death. What they meant by this definition was the fact that as soon as death sets in, the body begins to disintegrate. They argued correctly that the forces of disintegration were inherent in the living body but were held in check during life. Recent progress in physical chemistry permits us to state that the spontaneous disintegration of the body which sets in with death (at the proper temperature and proper degree of moisture) is a process of digestion, comparable to that which the meat we eat undergoes in our stomach and intestine. The essential feature of digestion is in this case the transformation of the solid meat into soluble products by two ferments, pepsin, which exists in the stomach, and trypsin, which exists in the intestine. The successive treatment of meat by the two ferments results in the breaking-up of the large insoluble molecules into the small soluble molecules of amino acids which are absorbed by the blood and carried to the cells of the body where they are utilized to build up new solid cell matter.

These two ferments, pepsin and trypsin, exist not only in the digestive organs, but in many, and possibly in all living cells, and the question arises, why they do not constantly digest and thus destroy our body while life lasts. A tentative answer

to this question has been given by Dernby, who has been able to show that the cooperation of both ferments is required in the same cell for the work of destruction, and that this cooperation of both ferments becomes possible only at a certain degree of acidity, which cannot be reached in the living body on account of the constant removal of acid through respiration and oxidation. When respiration ceases, the degree of acidity necessary for the digestive action of both ferments in the same cell is reached, leading to gradual digestion and liquefaction of the tissues which characterizes the disintegration of the dead body.

This is not the only cause of disintegration, since the dead body becomes also the prey of the destructive action of microorganisms from the air and in the intestine. During life these same microorganisms are powerless in their attack on the cells protected by a normal membrane, but after death this membrane is destroyed and the action of microorganisms can superimpose itself on that of digestion. It is also probable that the normal secretions of the mucous membranes during life have a protective effect.

Death, then, in a human being means the permanent cessation of respiration. We know that this result can be brought about by mechanical violence, by poison, and by disease, and, since nobody can escape all these agencies, doubts have arisen whether we do not all die from injury or disease, and whether such a thing as natural death really exists. If there were no natural death it should be possible to prolong life indefinitely if a complete protection against disease and accidents could be secured. It is impossible to make such an experiment in a human being, since our intestine and our respiratory tract can not be kept free from microorganisms. The problem has, however, been solved for certain insects. A Russian author, Bogdanow, invented a method of obtaining the common housefly free from all microorganisms, by putting the newly laid eggs for a number of minutes into a solution of bichloride of mercury of sufficient concentration. Most eggs were killed in the process, but some survived and these were free from microorganisms at their surface. By keeping the eggs on sterilized meat and in sterile flasks, the maggots leaving the egg could find their food and develop into flies. A French author, Guyénot, continuing the experiments on the fruit fly, raised 80 successive aseptic generations, and Northrop and the writer have raised thus far 87 aseptic successive generations of the

fruit fly on aseptic yeast. In these experiments all possibility of infection, all chances of accidental or violent death were excluded. To make sure that these flies are absolutely free from microorganisms, their dead bodies are transferred to culture media such as are used for the growth of bacteria. If a common fruit fly is put on such a culture medium, in 24 hours a rapid growth of microorganisms develops, while the culture medium on which our aseptic flies were put remained free from all growth for years (or rather permanently). Aseptic fruit flies, free from infectious disease and supplied with proper food will, therefore, not escape death. These experiments, then, indicate that higher organisms must die from internal causes even if all chance of infection and all accidents are excluded.

II

These aseptic flies served as a means for testing an idea concerning the duration of life which presented itself, namely, that old age and natural death are due either to the gradual production in the body of a sufficient quantity of harmful or toxic substances, or to the gradual destruction of substances in the body required to keep it in youthful vigor, or to both. On this basis the natural duration of life would be in reality the time required to complete a chemical reaction or a series of chemical reactions, resulting in the production of toxic compounds in a quantity sufficient to kill, or resulting in the destruction of necessary compounds. Metchnikoff had called attention to the fact that toxic substances were formed in the intestines under the influence of microorganisms. The intestine of aseptic flies is free from microorganisms, so that the source for the shortening of life pointed out by Metchnikoff need not be considered in this case. The toxic substances formed might be substances formed in one or several organs of the body during their normal activity. Modern physical chemistry furnishes the means of testing such an idea. The period of time required to complete a chemical reaction diminishes rapidly when the temperature is raised and increases rapidly when the temperature is lowered. Exeriments show that the time required for the completion of a chemical reaction is doubled or trebled when the temperature is lowered by 10° centigrade. This influence of temperature upon the rate of processes of nature seems to be typical for chemical reactions. If, therefore, the duration of life is the time required for the completion of certain chemical reactions in the body we might

expect that the duration of life will be doubled or trebled when we lower the temperature ten degrees centigrade. Such experiments can be carried out only in organisms where accidental death by infection is excluded and our aseptic fruit flies satisfied this condition. These experiments were made by Dr. Northrop and the writer, and consisted in putting a number of newly laid eggs of aseptic flies on an abundance of sterilized yeast (which is their natural food) in a flask plugged with cotton. These flasks were put into incubators the temperature of which was kept constant within 0.2 of a degree centigrade. The temperatures selected for the purpose were 10, 15, 20, 25, 27.5, and 30° C. It is not possible to go into the numerous precautions which it was necessary to take and the many technical difficulties involved in this investigation. The result of a large number of experiments was that the duration of life of such aseptic flies was a definite one for each temperature, which means that all the flies died at practically the same age when kept at the same temperature. Thus, for instance, the total average duration of life of such flies was 21.15 days at 30° C. The overwhelming majority died at that age, but a few died a little earlier and a few a little later. When the number of flies of a culture which die on successive days is plotted in terms of percentage of the original number of flies, we get that curve of death rates usually given in life insurance statistics. But this curve is very steep in our case owing to the fact that the majority of flies die at about the same time for a given constant temperature. The following table gives the average duration of life of the fly in days for different temperatures.

TABLE I

Temperature, °C.	Average Duration of Life of the Fly from Egg to Death, Days
30	21.15
25	38.5
20	54.3
15	123.9
10	$177.5 + x$

This table shows that the influence of temperature on the duration of life of the fly is the same as the influence of temperature on the velocity of a chemical reaction, inasmuch as a lowering of the temperature by ten degrees results in an increase in the duration of life by two or three hundred per cent., and the same figure would be obtained if we investigated the effect of temperature upon the time required to complete a chemical reaction. At 30° C. the flies live on an average 21.15

days and at 20° C. they will live on an average 54.3 days or a little over twice as long. At 25° they live 38.5 days and at 15° C. 123.9 days or about three times as long. The fruit fly is a tropical organism and 30° C. is not far from the optimal temperature. By lowering their temperature twenty degrees we prolong the duration of their life by nine hundred per cent. We cannot lower the temperature below 10° since the flies suffer in the chrysalid stage when the temperature becomes 10° or less. While these are thus far the only experiments on the duration of life of higher organisms carried out with the necessary scientific precaution, there are many casual observations mentioned in the literature which suggest that lowering the temperature prolongs the duration of life of lower animals in general.

The body temperature of a normal human being is constant, namely about 35.5° C. and this temperature remains the same in the tropics and in the arctic regions. Human beings and most mammals differ in this respect from insects whose temperature is as a rule practically that of their surroundings. If if were possible to reduce the temperature of human beings and if the influence of temperature on the duration of life were the same as that in the fruit fly, a reduction of our temperature from 37.5 to about 16° would lengthen the duration of our life to that of Methusaleh; and if we could keep the temperature of our blood permanently at 7.5° C., our average life would (on the same assumption) be lengthened from three score and ten to about 27 times that length, *i.e.*, to about nineteen hundred years. Unfortunately our body does not tolerate any considerable lowering of its temperature and if it did, life at so low a temperature would probably become very monotonous and uninteresting since in all probability sensations of pleasure as well as pain, of joy and of sadness, would be at a very low level.

The experiments on aseptic flies therefore lend support to the idea that the duration of our life is the time required for the completion of a chemical reaction or a series of chemical reactions. If these reactions consist in the gradual accumulation of harmful products in our body, or in the gradual destruction of substances required for a youthful condition, we understand why senile decay and death are the natural result of life.

III

Unicellular organisms, like bacteria, algæ or infusorians, seem to be immortal. They reach a certain size, divide into

two, each half growing again to full size and dividing again, and so on. In this case we may say that it is practically the same individual which continues to live in the successive generations. Small pieces of a cancerous tumor can be transplanted successfully to other individuals and these pieces grow again to a large size. This process can also be repeated indefinitely, and it is the same cancer cell which continues to live in these successive transplantations, as it is the same bacterium which continues to live in successive generations. In this way it has been shown that cancers in mice may outlive many times the natural life of a mouse, in fact they seem to live indefinitely. Cancer cells may therefore be called immortal as was pointed out by Leo Loeb many years ago.

It seems that this is true also for certain normal cells like connective tissue cells. Carrel has isolated connective tissue cells from the heart of a chick embryo and cultures of these cells living on the extracts from chick embryos have been kept alive now for seven years.

All this points to the idea that death is not inherent in the individual cell, but is only the fate of more complicated organisms in which different types of cells or tissues are dependent upon each other. In this case it seems to happen that one or certain types of cells produce a substance or substances which gradually become harmful to a vital organ like the respiratory center of the medulla, or that certain tissues consume or destroy substances which are needed for the life of some vital organ. The mischief of death of complex organisms may then be traced to the activity of a black sheep in the society of tissues and organs which constitute a complicated multicellular organism.

IV

While in human beings there is no sharp limit between youth and maturity, in many insects and amphibians this limit is marked by a sudden metamorphosis in the shape of their body. The frog hatches from the egg as a tadpole without legs and with a long tail. After a certain length of time legs begin to grow, the tail disappears, the form of the head and mouth change, the skin looks different, and the tadpole is transformed into a frog. It is possible that some of the changes underlying metamorphosis are due to changes in the circulation of the blood. Gudernatsch made the remarkable discovery that this metamorphosis, which in our climate usually occurs during the third or fourth month of the life of the tadpole, can be brought

about at will even in the youngest tadpoles, by feeding them with thyroid gland, no matter from which animal. By feeding very young tadpoles with this substance, frogs not larger than a fly could be produced. Allen added the observation that if a young tadpole is deprived of its thyroid gland, it is unable ever to become a frog; and that it remains a tadpole which can reach, however, a long life and continue to grow beyond the usual size of the tadpole. When, however, such superannuated tadpoles are fed with thyroid they promptly undergo metamorphosis. These observations cleared up an old biological puzzle. Salamanders also go through a metamorphosis which is, however, less striking than that of the tadpole of a frog. In the salamander the metamorphosis consists chiefly in the throwing off of the gills, and in changes in skin and tail. In Mexico a salamander occurs which through its whole life maintains its tadpole form, namely the axoloti. Attempts to induce the axolotl to metamorphose failed until after Gudernatsch's discovery an investigator fed the axolotl thyroid gland, and this brought about metamorphosis. The thyroid gland stores the traces of iodine taken up in our food and it seemed possible that the iodine contained in the thyroid was the active principle causing metamorphosis in tadpoles. This was confirmed by Swingle who succeeded in inducing metamorphosis in tadpoles by feeding them with traces of inorganic iodine. According to our present knowledge, the duration of the tadpole stage seems to be the time required to store the necessary amount of certain compounds, one of which contains iodine.

Insects, like the fruit fly, hatch from the egg as maggots which grow at the expense of the food they take up and which, at a certain age, metamorphose into a chrysalid; and from this chrysalid at a given time will rise the winged fly. Feeding of thyroid to the maggots of the fruit fly will not accelerate their metamorphosis, and we can not yet tell whether in this case metamorphosis is due to the accumulation or formation of a definite compound in the body, though this may well be the case. The idea presented itself whether the duration of the larval or maggot stage was not also determined by the temperature (provided the food supply was adequate). We measured, therefore, the influence of temperature upon the duration of the larval state in aseptic fruit flies—*i.e.*, from the time the egg was laid until the maggot was transformed into a chrysalid. The influence was practically identical with that of temperature on the total duration of life. Thus the larval period lasted 5.8 days at

25° C. and 17.8 days at 15° C., a ratio of about 1:3. The total duration of life of aseptic flies is 38.5 days at 25° and 123.9 days at 15° C., also a ratio of about 1:3. We are, therefore, justified in making the statement that the influence of temperature upon the duration of the larval period or the youth of aseptic flies is practically identical with the influence of temperature on the total duration of life.

Experiments by Uhlenhuth on the influence of temperature on metamorphosis in salamanders have shown that it is similar to that observed in flies. Salamanders kept at 25° metamorphosed when they were 11 weeks old, while salamanders kept at 15°, under otherwise identical conditions, metamorphosed when they were 22 weeks old. All these data suggest the possibility that the duration of life and the duration of the larval period or of youth are in reality times required for the completion of definite chemical reactions. The cessation of respiration leading to the termination of life and the alterations in circulation leading to metamorphosis or termination of youth are critical points; and it seems possible that these points are reached when a certain toxic substance is formed in adequate quantity in the body, or when a necessary substance is destroyed or sufficiently diminished in quantity, or when both conditions are fulfilled.

We can prolong or shorten the period of youth in amphibians not only by modifying the temperature but by withdrawing or offering the specific substance which causes metamorphosis, namely iodine or thyroid material. There is no end to the substances capable of hastening death. Shall we ever find a substance which will prolong the duration of life? At present we can neither deny nor affirm the possibility.

THE PROGRESS OF SCIENCE

THE PRINCIPLE OF RELATIVITY AND THE DEFLECTION OF LIGHT BY GRAVITATION

CABLE despatches from England report a joint meeting on November 6 of the Royal Society and the Royal Astronomical Society, at which Sir F. W. Dyson, the astronomer royal, and Dr. A. C. Crommelin, of the Royal Observatory at Greenwich, announced that an examination of the photographic plates taken during the solar eclipse of last May show a deflection of the rays of light from the stars in their passage past the sun that accords with the theoretical degree predicted by Dr. Albert Einstein's theory of relativity, namely, 1.7 second of arc.

In the solar eclipse of 1918 the Lick Observatory photographed the stars in the region immediately surrounding the sun in order to test the Einstein theory, but the results seem not to have been published. There is presumably no question about the correct measurement of the English plates. The same results seem to have been obtained from the photographs which had been taken at Sobral in north Brazil and at the Island of Principi off the African west coast. Neither does there appear to be any alternate explanation of the phenomenon. Professor H. F. Newall, of Cambridge, is said to have suggested at the meeting that it might be due to an unknown solar atmosphere, further in extent than had been supposed and with unknown properties, but it is not clear how a hypothesis in itself unlikely would account for the deflections, if they are those called for by the Einstein theory.

It is further the case that the theory had already been confirmed by another astronomical fact, the motion of the planet Mercury, which accords with the theory of relativity, but can not be accounted for on the exact assumptions of Newton's law of gravitation. On the other hand, a shift of the lines in the spectrum toward red in a strong gravitational field, which the Einstein theory requires, has been looked for unsuccessfully.

The experiment of the English astronomers is in itself very simple. If the rays from the stars are deflected by the gravitational field of the sun, this can not ordinarily be observed, for it is impossible to photograph them in the sun's light. But at the time of a total eclipse the bright stars, far beyond the sun but near it in the firmament, can be photographed, and their apparent positions can be compared with the positions of the same stars when the rays do not pass near the sun. The change in the apparent positions of the stars, presumably through deflection of their light by gravitation, can thus be readily measured.

Sir J. J. Thomson, the president of the Royal Society, is reported to have said at the meeting that it was the greatest discovery in connection with gravitation since Newton enunciated that principle. This in itself might not mean much, for no discovery in regard to gravitation has been made since the time of Newton. But if the results lead to the acceptance of the whole theory of relativity, as developed by Einstein, then indeed not only our theories of gravitation and the ether, but our whole conception of space, time, mass and

motion must be altered more fundamentally than has ever before occurred in the history of science.

A clear account of the theory of relativity by Professor William Marshall, of Purdue University, will be found in the MONTHLY for May, 1914. Albert Einstein, then employed in the Swiss patent office, formulated the theory in 1905 with remarkable perfection in a short article entitled "Concerning the electrodynamics of moving bodies." In 1911 he published the paper which deduces the influence of gravity on the propagation of light which is said now to be confirmed by the astronomical observations. Dr. Einstein was appointed to a chair in the Zurich Polytechnic School and was later called to one of the research institutions established in affiliation with the University of Berlin.

The Einstein theory may be said to have had its origin in an effort to explain the experiment on the so-called ether-drift, made by Professors Michelson and Morley somewhat more than thirty years ago at the Western Reserve University. Michelson suggested that the negative result of the experiment could be accounted for by supposing that the apparatus underwent a shortening in the direction of the line of motion. Later Professor Lorenz, the Dutch physicist, assumed that everything gets shortened as it moves through space; that the 8,000 miles of the earth's diameter is shortened up by three or four inches, an amount sufficient to provide a scientific explanation for the failure of the Michelson and Morley attempt to detect that the earth was moving through the ether. Then Einstein proposed his generalization that it is impossible to detect the effects of motion, except when it is relative to another material body, or that it is impossible to detect the absolute velocity of any body through space.

Many queer things have been written and will be written in the daily press concerning the theory of relativity, but perhaps none more strange than the logical deductions from the theory. As an example, Einstein's words (as translated by Professor Wetzel in *Science*, October 3, 1913), in the paper of 1911, may be quoted:

> Give the watch a very large velocity (approximating the velocity of light) so that it travels with uniform speed; after it has gone a long distance give it an impulse in the opposite direction so that it returns to its starting point. We then observe that the hand of this watch during its entire journey to and fro has remained practically at a standstill, while the hand of an exactly similar watch which did not move with respect to the coordinate system (the sun or earth) has changed its position considerably.
>
> We must add: what is true for our watch with respect to time must also be true of any other enclosed physical system, whatever its nature, because in all our thinking the watch was introduced simply as a representative of all physical actions or occurrences. Thus, for example, we could substitute for the watch a living organism enclosed in a box. Were it hurled through space like the watch, it would be possible for the organism, after a flight of whatever distance, to return to its starting point practically unchanged, while an exactly similar organism which remained motionless at the starting point might have given place to new generations. For the organism in motion time was but a moment, if its speed approached the velocity of light. This is a necessary consequence of our fundamental assumptions and one which experience imposes on us.

THE DISINTEGRATION OF ATOMS AND ATOMIC ENERGY

THE theory of relativity, though based on physical observations and

mathematical equations, seems to carry us into a metaphysical region remote from our normal interests. The discovery of radio-activity has opened new fields for exploration yielding results almost incredible, but not removed from our ordinary conceptions and everyday interests. At the recent centenary commemoration of James Watt, it was suggested by Sir Oliver Lodge that if Watt were living to-day he would be directing his attention to discovering whether there are other stores of energy at present almost unsuspected. The fact was that contained in the properties of matter there was an immense source of energy so far inaccessible, but which he saw no reason why the progress of discovery should not make available. He referred to atomic energy which, if it could be utilized on an extensive scale, would, he believed, greatly ameliorate the conditions of factory life. There would be no smoke due to imperfect combustion and no dirt due to the transit of coal or ashes, while the power would be very compact and clean. Possibly there might occasionally be explosions due to the liberation of power more quickly than it was wanted, but in general he presumed that the conditions of utilization would be good.

Sir Oliver explained that the secret of this power began to be given away when radio-activity was discovered, and said that at present we were hardly at the beginning of its utilization. The discovery of radium, which soon followed, excited universal interest and aroused great surprise, because radium appeared to give off energy continually without being consumed. The truth was that it did disappear as it gave off its energy, but the disappearance was so slow and the energy given off so remarkable that it was not surprising that one was noticed before the other. The energy of radium, however, was not under control, and it went on emitting energy at its own proper rate without regard to accidental circumstances. What happened was that every now and then a particle was projected. The energy stored in an atom was something enormous, and if we could make the atoms fly off when we wanted there would be available a source of energy which would put everything else into the background. This energy was contained in all forms of matter and was not confined to radio-active substances. If a stimulus could be found the utilization of this source of energy would be possible. We appeared to be on the verge of utilizing a minute fraction of it, and it was this energy which had made wireless telephony possible.

Those familiar with Sir Oliver Lodge's communications with the spirit world may regard his information concerning the energy of atoms as equally speculative, but this is by no means the case. Sir Ernest Rutherford has recently given a lecture before the Royal Institution in which he described experiments which are incontrovertible even though the explanation that he adduces may not be final.

The swift α-particles and the high-speed electrons or β-rays ejected from radio-active bodies are by far the most concentrated sources of energy known to science. The enormous energy of the flying α-particles or helium atom is illustrated by the bright flash of light it produces when it impacts on a crystal of zinc sulphide, and by the dense distribution of ions along its trail through a gas. This great store of energy is due to the rapidity of its motion, which in the case of the α-particle of radium C amounts to

19,000 km. per second, or about 20,000 times the speed of a rifle-bullet. The energy of motion of an ounce of helium moving with the speed of the α-particle is equivalent to 10,000 tons of solid shot projected with a velocity of 1 km. per second.

Sir Ernest Rutherford found from the scintillations on a zinc sulphide screen that when an α-particle strikes an atom of nitrogen the latter is broken down and a long range atom, which is not nitrogen, arises from the collision. This atom is held to be a charged atom of hydrogen or an atom of mass 2. Sir Ernest says that taking into account the great energy of the particle, the close collision of an α-particle with a light atom seems to be the most likely agency to promote its disruption. Considering the enormous intensity of the forces brought into play in such collisions, it is not so much a matter of remark that the nitrogen atom should suffer disintegration as that the α-particle itself escapes disruption. The results, as a whole, suggest that if α-particles, or similar projectiles of still greater energy, were available for experiment, we might expect to break down the nucleus structure of many of the lighter atoms.

INTERNATIONAL SCIENCE AND THE WAR

AN appeal has been addressed to the members of the academies of the allied nations and of the United States by 177 members of the academies of neutral nations—Holland, Norway, Sweden, Denmark, Finland and Switzerland—represented in the International Association of Academies, the opening and concluding paragraphs of which are as follows:

In the autumn of 1813, when for years a most bitter war had been raging between France and England, the English chemist Humphry Davy set out for Italy via Paris. His biographer relates what follows about his experiences in the French capital: "Nothing could exceed the cordiality and warmth of Davy's reception by the French savants. On Nov. 2nd he attended a sitting of the First Class of the Institute and was placed on the right hand of the President, who announced to the meeting that it was honoured by the presence of 'le chevalier Davy.' Each day saw some reception or entertainment in his honour. . . . On Dec. 13th, 1913 he was with practical unanimity elected a corresponding member of the First Class of the Institute."

On October 2, 1918, when a most bitter war raging between France and Germany for four years had practically come to an end, it is stated in a meeting of the French Academié des Science, that "elle a été unanime à déclarer que les relations personnelles sont pour longtemps impossibles entre les savants des pays alliés et ceux des empires centraux," so that "nous devons abandonner les anciennes associations internationales, et en créer de nouvelles entre alliés avec le concours eventuél des neutres."

Whence this painful contrast? We should rather have expected the opposite, even without indulging illusions with regard to the progress of mankind during a hundred years. For there seems to be more room for generosity when the war's misery is past than when it is still raging; more too towards a defeated enemy than towards one who is still to be feared.

. . . . . .

Summing up what precedes we ask you earnestly and urgently: Recover your former selves. Recover the high scientific point of view which, on his deathbed, made Ampère say to a fellow worker: "il ne doit être question entre nous que de ce qui est

eternel!" Once more: we understand how your attention of late has been monopolized by what is temporal and transitory. But now, you more than all the others, are called upon to find again the way to what is eternal. You possess the inclination for objective thought, the wide range of vision, the discretion, the habit of self-criticism. Of you we had expected the first step for the restoration of lacerated Europe. We call on you for cooperation in order to prevent science from becoming divided, for the first time and for an indefinite period, into hostile political camps.

SCIENTIFIC ITEMS

WE record with regret the death of Charles Henry Hitchcock, for forty years professor of geology at Dartmouth College.

DR. SIMON FLEXNER, director of the laboratories of the Rockefeller Institute for Medical Research, Dr. Theodore W. Richards, professor of chemistry at Harvard University, and director of the Wolcott Gibbs Memorial Laboratory, and Dr. R. W. Wood, professor of physics in the Johns Hopkins University, have been elected foreign members of the Royal Society of London.

DR. FRANK SCHLESINGER, of the Allegheny Observatory, was elected president of the American Astronomical Society at the recent Ann Arbor meeting. Dr. Schlesinger succeeds the late Edward C. Pickering, who for many years in succession had been elected to this office.—At the October meeting of the executive board of the National Research Council Professor Vernon Kellogg, of Stanford University, was elected executive secretary of the council.

ANNOUNCEMENT is made that Mr. John D. Rockefeller has added $10,000,000 to his previous endowment of the Rockefeller Institute for Medical Research. This gift, the largest made by Mr. Rockefeller at one time to the institution, is to meet rapidly growing needs in its many lines of research and in making new knowledge available in the protection of the public health and in the improved treatment of disease and injury.

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The Digestibility of the Branny Coats of Wheat, Charles H. Briggs.

The Introductory Course in Zoology, Professor George LeFevre.

Scientific Events:—
Changes in the French Population in 1918; A Pueblo Ruin in New Mexico; The American Congress of Surgeons.

Scientific Notes and News.

University and Educational News.

Discussion and Correspondence:—
Natural Field Sanitation in China, Atherton Lee. A Method of Embedding in Paraffine, Dr. Leo H. Schatz.

Quotations:—Scientific and Industrial Research.

Scientific Books:—
Smith and Cheshire on Constructional Data for Small Telescope Objectives, Professor Henry S. White.

Special Articles:—
Electrolytes and Colloids, Dr. Jacques Loeb.
The American Chemical Society, Dr. Charles L. Parsons.

FRIDAY, NOVEMBER 14, 1919

Industrial Research in Small Establishments, Morris E. Leeds.

The Naturalist's Place in His Community, W. E. Allen.

Charles Conrad Abbott and Ernest Volk, Professor G. Frederick Wright.

Scientific Events:—
International Science and the War; The League of Red Cross Societies; The Tariff on Scientific Apparatus; The New York Botanical Garden; Gift to the Rockefeller Institute for Medical Research.

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Substitutes for the Words Homozygous and Heterozygous, Dr. Frank J. Kelley. Some Port Hudson Outcrops in Louisiana, The Late F. V. Emerson.

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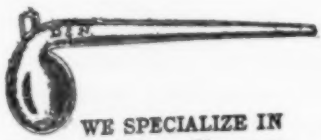

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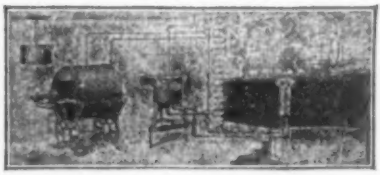

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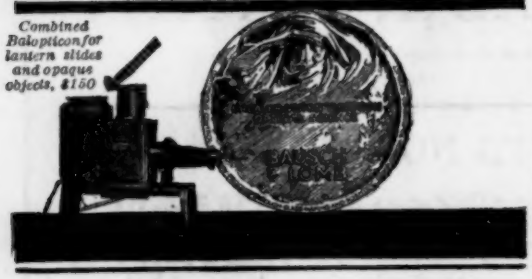

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